# Master's, Doctoral, and Post-doctoral Track Program: Chemistry and Materials Science

## 1. Open Doors winner's skill set by Subject

Winning the Open Doors competition requires a firm grasp of the following concepts and themes:
• fundamental principles of analytical, organic, inorganic, physical, and nuclear chemistry;
• core concepts in chemical engineering and materials science;
• theoretical foundations and methodologies used in modern chemical research;
• environmental safety and sustainability considerations in chemical processes;
• the role of chemistry in addressing current scientific and industrial challenges;

The winner is expected to demonstrate a solid command of the following skills:
• solving discipline-specific problems using theoretical knowledge and modern techniques;
• conducting and interpreting qualitative and quantitative chemical experiments;
• applying modern tools and approaches, including modelling, simulation, and data analysis;
• operating laboratory equipment and using relevant software for research and experiment design;
• demonstrating scientific reasoning and critical thinking in research contexts;
• integrating principles of sustainability and environmental responsibility into chemical practice.

## 2. List of degree programs covered by the subject area

### 2.1. List of doctoral degree programs

1. 4. 1 Inorganic Chemistry
1. 4. 2 Analytical Chemistry
1. 4. 3 Organic Chemistry
1. 4. 4 Physical Chemistry

### 2.2. List of master's degree programs

04.04.01 Chemistry
18.04.01 Chemical Engineering
22.04.01 Materials Science and Engineering
18.04.02 Energy and Resource Saving Processes in Chemical Engineering, Petrochemistry and Biotechnology
04.04.02 Chemistry, physics and mechanics of materials

## 3. Content

### Field of science 1. Analytical Chemistry

1. Protolytic theory. Application of the law of mass action to acid–base equilibria. Calculation of pH in aqueous solutions. Buffer solutions
2. Complexation reactions. Basic concepts, types of coordination compounds. Equilibrium in complex formation reactions. Stability of complex compounds
3. Qualitative chemical analysis. Methods of performing analytical reactions. Concept of analytical signal. Main analytical groups of cations and anions
4. Titrimetric analysis methods. Methods for expressing solution concentration. Titration curves. Calculation of analyte mass in solution. Techniques for performing titrimetric analysis.
5. Types of titrimetric analysis. Acid–base titration. Complexometric titration. Redox (oxidation–reduction) titration. Precipitation titration.

### Field of science 2. Organic Chemistry

1. Structure of organic molecules: nature of chemical bonds, electron density distribution in molecules, types of isomerism in organic compounds, concept of aromaticity in carbocyclic and heterocyclic systems
2. Major classes of organic compounds, methods of their synthesis and chemical transformations. Relationship between molecular structure and reactivity.
3. Concepts of basicity and acidity of organic molecules; factors affecting the stability of reactive intermediates (carbocations, free radicals, etc.)
4. Reaction mechanisms considering electronic and steric effects of reagents and substrates; regioselectivity and stereoselectivity of reactions
5. Natural sources of organic compounds; key laboratory and industrial methods for synthesizing major classes of organic substances
6. Principles of rational organic synthesis; use of protecting groups; basics of the retrosynthetic approach
7. Organic compounds as pharmaceuticals or functional materials, including polymers
8. Organic substances of natural origin; interaction of organic compounds with living systems; environmental considerations in organic chemical production
9. Fundamentals of molecular spectroscopy (IR, UV, NMR), mass spectrometry and X-ray diffraction

**Field of science 3. Physical Chemistry**

1. The first law of thermodynamics and its application (internal energy, enthalpy, heat and work)
2. Thermochemistry, heat capacities, Hess's law, Kirchhoff's equation
3. The second law of thermodynamics (entropy, thermodynamic potentials and characteristic functions)
4. Fundamental Gibbs relation, Gibbs-Helmholtz equations, Planck's postulate (third law of thermodynamics), chemical potential
5. Phase equilibria: heterogeneous systems, Gibbs phase rule, Clausius-Clapeyron equation. Thermodynamic properties of solutions. Raoult's laws
6. Phase equilibria in two-component liquid-vapor systems. Phase equilibria in condensed systems
7. Thermodynamics of electrochemical systems: electromotive force of an electrochemical cell, electrode potential. Nernst equation
8. Electrical conductivity of electrolyte solutions, ion mobility, the Debye-Huckel theory
9. Chemical kinetics and catalysis: the effect of temperature on the reaction rate, the Arrhenius equation, activation energy, methods for determining it
10. Chemical equilibria: the law of mass action and the equilibrium constant, isotherm and isobar equations of a chemical reaction

**Field of science 4. Chemical Engineering and Industry**

1. Modern chemical engineering processes and their intensification (including reactor technologies, energy saving and increasing process selectivity)
2. Modeling and optimization of chemical production. Mathematical modeling, software, calculation of balances and optimization of modes
3. Design and analysis of process flow, process chains, selection of equipment, analysis of technical and economic indicators
4. Physico-chemical principles of processing raw materials and obtaining chemical products (inorganic, organic and polymer raw materials, recycling, alternative resources)
5. Substances quality control and analysis methods in chemical technologies (chromatography, spectroscopy, thermal analysis, etc.)
6. Environmentally friendly and resource-saving technologies. ‘Green’ chemistry, waste disposal, closed cycles, emissions and purification

7. Materials and processes in the chemical industry (catalysts, membranes, ion exchangers, packaging and functional materials)
8. Risk assessment, reliability and safety of chemical production

**Field of science 5. Inorganic and Nuclear Chemistry**
1. Classification and properties of inorganic compounds (oxides, acids, bases, salts, amphoteric compounds)
2. Types of chemical bonds and spatial structure of molecules (ionic, covalent, metallic, coordination bonds; the valence shell electron pair repulsion (VSEPR) theory, hybridization)
3. Redox processes in solutions and solid phases (redox-reaction calculation methods, electron balance, application in analytical and industrial chemistry)
4. Equilibrium in aqueous electrolyte solutions (strong and weak electrolytes, pH, hydrolysis, buffer solutions)
5. Acid-base interactions and theories of acids and bases (Arrhenius, Brønsted-Lowry, Lewis; acid-base properties of complex compounds)
6. Complex compounds: structure, isomerism and equilibrium in solution (crystal field theory, isomerism, stability of complexes, chelation)
7. Fundamentals of coordination chemistry and organometallic compounds (structure and reactivity, application in catalysis)
8. Radiochemistry and chemistry of nuclear transformations (types of radioactive decay, kinetics and thermodynamics of nuclear reactions, nuclear fuel)
9. Methods of obtaining, separating and analyzing inorganic substances and isotopes (precipitation, extraction, chromatography, ion exchange, radiometric methods)
10. Safety and ecology in inorganic and nuclear chemistry (radioactive waste management, protection from ionizing radiation, standards).

**Field of science 6. Materials science**
1. Modern methods of studying the materials composition and structure (X-ray diffraction analysis, scanning electron microscopy, spectroscopic methods, tomography, probe microscopy methods)
2. Physico-chemical principles of the materials structure formation (phase diagrams, crystallization, heat treatment, diffusion)
3. Mechanical, electrical, optical and other materials properties (elasticity, strength, hardness, conductivity, thermal conductivity, photosensitivity)
4. Structure, defects and fractures in materials (dislocations, microcracks, porosity, fracture analysis, fracture micromechanics)
5. Processes of obtaining and modifying materials (fusion, spraying, chemical deposition)
6. Statistical methods of processing and interpreting experimental data (error assessment, confidence intervals, correlation and regression analysis)
7. Computer modeling and calculation of material properties (molecular dynamics methods, finite-element method, modeling of processing and fracture processes)
8. Multidisciplinary analysis of materials and their applications (biomaterials, functional coatings, composite structures)
9. Experimental methods for obtaining new materials and optimizing their properties (material design, component selection, experimental planning)

## 4. Preparation materials
### 4.1 Recommended reading

**Field of science 1. Analytical Chemistry**

| **Sources in English** |
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| Analytical Chemistry. Gary D. Christian, 6th ed. 2004. 850 p. URL://https://chemistrydocs.com/analytical-chemistry-6th-edition-by-gary-d-christian/ |
| Christian G.D., Dasgupta K. (Sandy), Schug K.A. Analytical chemistry. Seventh edition. John Wiley & Sons, Inc, 2014. 826 p. URL://https://kvmwai.edu.in/upload/StudyMaterial/Analytical-Chemistry-by-Gary-D_-Christian-Purnendu-K_-Dasgupta-Kevin-A_-Schug-z-lib_org_.pdf |
| Harvey D.T. Analytical chemistry 2.1. DePauw University, Inc. 2016. 1122 p. URL://https://open.umn.edu/opentextbooks/textbooks/486 |

**Field of science 2. Organic Chemistry**

| **Reading list in English** |
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| Clayden J., Greeves N., Warren S. Organic Chemistry. Oxford University Press, 2000. Organic Chemistry, 2012. 1265 p. URL://https://blogmedia.testbook.com/kmat-kerala/wp-content/uploads/2023/06/organic-chemistry-by-jonathan-clayden-nick-greeves-stuart-warren-z-lib.org_-847123c1.pdf |
| Hart H. Organic Chemistry – A Short Course. Cengage Learning, 2011. 600 p. URL://https://archive.org/details/organicchemistry0000hart_p9s2 |
| Jerry M. Advanced Organic Chemistry: Reactions, Mechanisms, and Structure (6th ed.)/ New York: Wiley-Interscience, 2007. 1376 p. URL://https://archive.org/details/advanced-organic-chemistry-jerry-March |

**Field of science 3. Physical Chemistry**

| **Reading list in English** |
|---|
| Atkins P. and de Paula J. Physical Chemistry. New York: W. H. Freeman and Company, 2006. 1053 p. URL://https://djvu.online/file/kXPWmnlehd4tA?ysclid=lzwmbbqoin691282238 |
| Hofmann, A. Physical Chemistry Essentials. Springer, Cham., 2018. pp. 1-11. URL://https://doi.org/10.1007/978-3-319-74167-3_1 |
| Job G., Rüffler R., Physical Chemistry from a Different Angle Workbook. Springer Cham, 2019. 291 p. URL://https://doi.org/10.1007/978-3-030-28491-6 |
| Keszei, E. Chemical Thermodynamics. Springer Berlin Heidelberg, 2012. 354 p. URL://https://doi.org/10.1007/978-3-642-19864-9 |

**Field of science 4. Chemical Engineering and Industry**

| **Reading list in English** |
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| Kealey D., Haines P.J. Analytical Chemistry. BIOS Scientific Publishers Limited, 2002. 352 p. URL://https://tech.chemistrydocs.com/Books/Analytical/Analytical-Chemistry-By-D-Kealey-and-P-J-Haines.pdf |
| Moulijn J.A., Makkee M., Van Diepen A.E. Chemical process technology. 2nd ed. Wiley, 2013. 539 p. URL://https://www.academia.edu/44116161/Chemical_Process_Technology#loswp-work-container |
| Norris shreve R. The chemical process industries. McGraw-Hill series in chemical engineering. McGraw-Hill Book Company, Inc. USA, 1956. 1004 p. URL: https://www.academia.edu/34515171/McGRAW_HILL_SERIES_IN_CHEMICAL_ENGINEERING_THE_CHEMICAL_PROCESS_INDUSTRIES |
| Staszak K., Wieszczycka K., Tylkowski B. Chemical Technologies and Processes. Poland: De Gruyte, 2020. 483 p. URL: https://oceanofpdf.com/authors/katarzyna-staszak/pdf-epub-chemical-technologies-and-processes-de-gruyter-stem-download/ |

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| Woolf P. J. Chemical Process Dynamics and Controls. Michigan: the University of Michigan, USA, 2006. 782 p. URL://https://open.umich.edu/sites/default/files/downloads/chemical_process_dynamics_and_controls-book_1.pdf |

**Field of science 5. Inorganic and Nuclear Chemistry**

| **Reading list in English** |
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| Atkins P.W, Overton T.L., Rourke J.P., Weller M.T., Armstrong F.A. Inorganic chemistry. Great Britain: Oxford University Press, 2010. 851 p. Press, 2010. 851p URL://https://chemistry.com.pk/books/shriver-atkins-inorganic-chemistry-5e/ |
| Handbook of Nuclear Chemistry, 2nd ed. Springer, 2011. 3087 p. URL://https://link.springer.com/referencework/10.1007/978-1-4419-0720-2 |
| Lee J.D. Concise Inorganic Chemistry for JEE (Main & Advanced), 4ed. Chapman & Hall, 1991. 718 p. URL://https://archive.org/details/conciseinorganicchemistrybyjdlee4ed |
| Overton T. L., Rourke J. P., Weller M. T., Armstrong F. A. Inorganic chemistry, 7th ed. Great Britain: Oxford University Press, 2018. 967 p. URL://https://zlib.pub/book/inorganic-chemistry-71ndlsulje40 |
| Petrucci R.H., Herring F.G., Madura J.D., Bissonnette C. General Chemistry: Principles and Modern Applications – 11th Edition. – Toronto: Pearson, 2017. 1496 p. URL://https://chemistry.com.pk/books/general-chemistry-11e-petrucci-herring/ |

**Field of science 6. Materials science**

| **Reading list in English** |
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| Callister W.D.Jr., Rethwisch D.G. Materials Science and Engineering, Wiley, 2014. 1000 p. URL://https://ftp.idu.ac.id/wp-content/uploads/ebook/tdg/TEKNOLOGI REKAYASA MATERIAL PERTAHANAN/Materials Science and Engineering An Introduction by William D. Callister%2C Jr.%2C David G. Rethwish (z-lib.org).pdf |
| Ghasem N. Modeling and simulation of chemical process systems, CRC Press, 2019. 519 p. URL://https://psv4.userapi.com/s/v1/d/Dy4Whusm7B66q3IA9OaNr74MkSKZVNVi6E-X09TpQKTVgfAdxXp0CfnasMYr6_9IGcILsl5D_paivWnvN-VCAwPfNLYbZB7zZ7yH02N0kKyhaFZdfsvbpg/Nayef_Ghasem.pdf |
| Lista L. Statistical Methods for Data Analysis with Applications in Particle Physics. Springer, 2023. 360 p. URL://https://link.springer.com/book/10.1007/978-3-031-19934-9 |
| Martin R.M. Electronic Structure: Basic Theory and Practical Methods, Cambridge University Press, 2004. 650 p. URL://https://stevencjxie8.com/files/refs/ref12.pdf |
| Perez N. Materials Science: Theory and Engineering, Springer, USA, 2024. 929 p. URL: https://link.springer.com/book/10.1007/978-3-031-57152-7 |

**4.1. Recommended online courses**

**Field of science 1. Analytical Chemistry**

| **Online courses in English** | **Link** | **Course description** |
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| Advanced Chemistry, Organic and Analytical Chemistry | https://alison.com/course/advanced-chemistry-organic-and-analytical-chemistry?utm_source=google&utm_medium=cpc&utm_campaign=Performance-Max_Tier-4_Careers&gad_source=1&gclid= | The course combines theoretical foundations with case-based learning in organic and analytical chemistry. It covers key topics such as atomic structure, electron behavior, nuclear fusion and |

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| | Cj0KCQjwvb-zBhCmARIsAAfUI2shCcr73QiEkyByyYwYngBDjeAauHvwoy02TtT4n8kXCGWBktBoCD4aAoz5EALw_wcB | fission, energy conversion, electrochemistry, and food chemistry. |
| Basic Analytical Chemistry | https://www.clas scentral.com/course/chemistry- the-university- of-tokyo-basic-analytica-10332 | This course introduces fundamental concepts and methods of analytical chemistry, with a focus on their application in chemistry and related fields, including the life sciences, environmental sciences, and geochemistry. |
| Analytical Chemistry | https://www.mo oc-list.com/course/ analytical-chemistry-saylororg | The course develops foundational knowledge in general chemistry, beginning with an introduction to key analytical terms. Students will learn concepts essential to the quantitative measurement of chemical substances, including sensitivity, detection limit, and limit of quantification. |
| Analitical Chemistry | https://www.clas scentral.com/course/swayam- analytical-chemistry-13895 | The course fosters the development of skills in the application of specialized instruments and advanced techniques for the separation, identification, and quantitative analysis of unknown substances. |

**Field of science 2. Organic Chemistry**

| **Online courses in English** | **Link** | **Course description** |
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| Basics of Chemistry of Heterocycles | https://stepik.org/course/137467/promo | The course aims to establish foundational knowledge in heterocyclic chemistry, with particular emphasis on key heterocyclic systems such as five-membered heterocycles (pyrrole, furan, thiophene), indole, pyridine, quinoline, and isoquinoline. For each heterocycle, the course covers electronic structure, synthetic methodologies, chemical properties, and characteristic reactions. |

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| Chemicals and Health | https://ru.coursera.org/learn/chemicals-health | The course explores the relationship between the environment and human health, focusing on chemical substances. It covers how chemicals enter the body (exposure), their biological effects (toxicology), methods for measuring chemical presence in the body (biomonitoring), and their impact on health. Additionally, the course addresses relevant policies and regulatory practices governing chemical safety. |
| Green Chemistry | https://openedu.ru/course/misis/GRCHM/?session=spring_2024 | The course consists of several thematic modules: introduction to green chemistry, green nanomaterials, green technologies in environmental protection and non-traditional chemical processes. |
| Organic Chemistry | https://www.youtube.com/playlist?list=PL0o_zxa4K1BXP7TUO7656wg0uF1xYnwgm | A series of video presentations covering the main topics of organic chemistry. |

**Field of science 3. Physical Chemistry**

| **Online courses in English** | **Link** | **Course description** |
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| Phase transformations | https://opened u.ru/course/sp bstu/PHTRAN S/ | The course introduces phase transformations occurring in alloys of binary phase diagrams. |
| Basics of thermodynamics | https://www.cl asscentral.com /course/thermo -dynamics- 23740 | This course offers a comprehensive introduction to the fundamental principles of thermodynamics, designed for a broad academic audience. It emphasizes essential concepts and core issues while deliberately excluding highly specialized or peripheral topics. The curriculum also addresses atypical phenomena, such as stretched liquids, and incorporates experimental demonstrations to facilitate a deeper conceptual understanding. |

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| Thermodynamics of Materials | https://www.classcentral.com/course/edx- thermodynami cs-of-materials-21137 | The course offers a comprehensive conceptual framework for understanding the fundamental interplay between energy and entropy that governs the equilibrium states of materials. It covers the laws of thermodynamics, the concept of equilibrium, and thermodynamic potentials, presenting both classical and statistical perspectives. |
| StanfordOnline: Thermodynamics and Phase Equilibria | https://www.edx.org/course/thermodynamics-and-phase-equilibria | This course offers a comprehensive introduction to thermodynamics, emphasizing its fundamental role in governing phase equilibria. It is designed for a broad audience and serves as essential preparation for students beginning their studies in thermodynamics at the bachelor's, master's, or doctoral level. |
| Colloids and Surfaces | https://www.classcentral.com/course/swayam-colloids- and-surfaces-19822 | The course provides an introduction to the fundamentals of colloid and nanoparticle science and discusses potential applications of these concepts. |
| Physical Chemistry: Help & Review | https://study.com/academy/course/physical- chemistry-help-review.html | The course provides a structured overview of key topics in physical chemistry, offering essential support for examination preparation, completion of assignments, or further academic and professional development. |

**Scientific field 4: Chemical Engineering and Industry**

| **Online courses in English** | **Link** | **Course description** |
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| Thermodynamics of Chemical Engineering 1 (Coursera) | URL://https://www.coursera.org/learn/chemtherm1 | This course provides a comprehensive introduction to thermodynamics, a foundational subject for students pursuing chemical and biomolecular engineering. Emphasizing its central role in assessing process viability, the |

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| | | course lays the groundwork for advanced topics such as reaction kinetics, mass and energy transfer, process design, and materials engineering. Given the growing global emphasis on energy efficiency and sustainability, thermodynamic principles are increasingly essential across engineering disciplines. The course covers the first and second laws of thermodynamics, with special attention to the behavior of non-ideal single-component and multicomponent systems. A substantial portion is dedicated to solution thermodynamics, which is fundamental for separation processes (e.g., distillation, extraction, and membrane technologies), as well as to chemical equilibria, which underpin the analysis and design of chemical reactions. |
| Numerical Methods Applied to Chemical Engineering | URL://https://ocw.mit.edu/courses/10-34-numerical-methods-applied-to-chemical-engineering-fall-2015/ | This course offers a comprehensive introduction to numerical methods used in chemical engineering to address complex problems in transport phenomena, reaction systems, and molecular modeling. Students will learn and apply numerical techniques for solving systems of linear and nonlinear algebraic equations, ordinary differential equations (ODEs), and partial differential equations (PDEs), with emphasis on applications such as heat and mass transfer, fluid flow, and reaction engineering. Special attention is given to the numerical treatment of the Navier–Stokes equations and to methods used in molecular simulations, including |

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| | | molecular dynamics and geometry optimization. All methods are taught within the context of real-world chemical engineering problems. Prior knowledge of structured programming is required. |
| Numerical Methods Applied to Chemical Engineering | URL://https://ocw.mit.edu/courses/10-34-numerical-methods-applied-to-chemical-engineering-fall-2005/ | This course provides an in-depth introduction to modern computational and mathematical methods used in chemical engineering analysis and design. It begins with the solution of linear systems as a foundational concept in scientific computing and extends to techniques for solving nonlinear algebraic equations, ordinary differential equations (ODEs), and differential-algebraic equations (DAEs). The course also introduces probability theory as a tool for physical modeling, along with statistical data analysis and parameter estimation. Finite difference and finite element methods are presented for transforming partial differential equations—arising from transport phenomena—into solvable DAE systems. Computational techniques are integrated throughout using the MATLAB® environment for practical implementation and demonstration. |
| Separation Processes | URL://https://ocw.mit.edu/courses/10-32-separation-processes-spring-2005/ | This course focuses on the application of scientific and engineering principles to the separation of chemical and biological mixtures. Emphasis is placed on the fundamental understanding and analysis of key separation processes, including distillation, membrane-based separations, chromatography, and |

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| | | adsorption. The primary objectives are twofold: to develop a conceptual and practical understanding of how separation processes operate, and to enhance students' ability to apply core principles of thermodynamics, mass transfer, and transport phenomena to the design and analysis of specific separation problems. |
| Integrated Chemical Engineering I | URL://https://ocw.mit.edu/courses/10-490-integrated-chemical-engineering-i-fall-2006/ | This course offers a comprehensive introduction to chemical process design, emphasizing the development, simulation, and optimization of process flowsheets. Students engage in practical assignments involving ABACUSS simulations, batch operations, and separation technologies. A key component of the course is the formulation of a base-case design, serving as the initial solution to an integrated process design challenge. Students evaluate the economic feasibility of the base case and iteratively improve the design by adjusting model parameters in consultation with instructors and teaching assistants. The course concludes with the submission of a formal technical report presenting the optimized design and supporting analysis. |
| Integrated Chemical Engineering II | URL://https://ocw.mit.edu/courses/10-491-integrated-chemical-engineering-ii-spring-2006/ | This course provides students with the foundational knowledge and methodological tools required for the conceptual design of continuously operating chemical plants. Emphasis is placed on the application of industry-standard process simulation software, such as Aspen Plus®, to address |

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| | | contemporary engineering challenges. Students work in teams to evaluate and design a specific chemical process technology. The course culminates in the preparation and submission of a comprehensive final design report that demonstrates the integration of process modeling, design principles, and economic considerations. |
| Mathematical modelling and simulation of chemical engineering process | URL://https://nptel.ac.in/courses /103105215 | This course offers an in-depth exploration of mathematical modeling approaches in chemical engineering, encompassing both deterministic and stochastic strategies. It provides a comprehensive theoretical framework for modeling transport phenomena, including heat transfer, mass transfer, and fluid dynamics. Emphasis is placed on the development and application of simulation techniques for these processes. The course also covers the modeling of dispersed phase systems and molecular-scale processes, equipping students with the skills necessary to analyze and predict the behavior of complex chemical engineering systems. |

**Field of science 5. Inorganic and Nuclear Chemistry**

| **Online courses in English** | **Link** | **Corse description** |
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| Introduction to Chemistry: Structures and Solutions | https://ru.coursera.org/learn/basic-chemistry | The course is designed to establish foundational knowledge in chemistry, emphasizing core concepts including atomic and molecular structure, solution chemistry, phase equilibria, and quantitative problem-solving techniques. It equips students with the essential |

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| | | theoretical and practical skills necessary for advanced study in chemistry and related disciplines. |
| General Chemistry: Concept Development and Application | https://ru.coursera.org/learn/general-chemistry | The course introduces key concepts and approaches in Inorganic Chemistry. |
| Introduction to Chemistry: Reactions and Ratios | https://ru.coursera.org/learn/intro-chemistry | The course focuses on the development of core competencies in Chemistry. The course includes fundamental concepts related to chemical reactions, stoichiometry, the periodic table, and chemical problem solving to prepare students for further study in chemistry. |
| Chemistry | https://ru.coursera.org/learn/chemistry-1 | The course provides students with a conceptual framework for understanding atomic structure, periodic patterns, compounds, reactions and stoichiometry, bonding and thermochemistry. |
| Advanced chemistry | https://www.coursera.org/learn/advanced-chemistry | The course aims to build foundational knowledge in Chemistry. |
| Introducti on to Coordinati on Chemistry | https://stepik.org/course/171575 | The course is designed to develop students' understanding of the fundamental principles and properties of coordination compounds, highlighting their significance and applications in everyday life. |

**Field of science 6. Materials sciences**

| **Online courses in English** | **Link** | **Course description** |
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| Materials Science for Technological Application (Coursera) | URL://https://www.coursera.org/specializations/materials-science-for-technological-application | The course focuses on atomic bonding and crystal structure, providing an in-depth examination of the role that materials play in modern engineering practice. |
| Fundamentals of Materials Science (Coursera) | URL://https://www.coursera.org/learn/fundamentals-of-materials-science | Materials science and engineering currently support most industrial sectors |

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| | | including aerospace, telecommunications, transportation, architecture, infrastructure, etc. Fundamentals of Materials Science is a core module for undergraduate students majoring in Materials Science and Engineering. This course takes an integrated approach to combining metallic, ceramic, and polymeric materials, enabling students to gain a deep understanding of the relationship between composition, microstructure, processing, and properties in materials science. |
| Materials Laboratory | URL://https://ocw.mit.edu/courses/3-014-materials-laboratory-fall-2006/ | The laboratory course integrates experimental investigations illustrating core principles of quantum mechanics, thermodynamics, and material structure with rigorous oral and written technical communication practice. Key topics include: empirical examination of the relationships among energetics, bonding, and material structure; application of these principles using advanced materials characterization techniques; demonstration of the wave-like behavior of electrons; practical training in quantifying energy (Differential Scanning Calorimetry, DSC), bonding (X-ray Photoelectron Spectroscopy, XPS; Auger Electron Spectroscopy, AES; Fourier Transform Infrared Spectroscopy, FTIR; Ultraviolet-Visible Spectroscopy, UV/Vis; force spectroscopy), and structural order (X-ray scattering) in condensed matter; and the |

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| | | exploration of structural phase transitions and structure–property correlations through hands-on materials case studies. |
| Fundamentals of Materials Science | URL://https://ocw.mit.edu/courses/3-012-fundamentals-of-materials-science-fall-2005/ | This course focuses on the fundamental concepts of structure, energetics, and bonding that form the basis of materials science. It introduces thermodynamic functions and laws governing equilibrium properties, linking macroscopic behavior to atomistic and molecular models of materials. The course examines the role of electronic bonding in determining the energy, structure, and stability of materials, alongside quantum mechanical descriptions of interacting electrons and atoms. Key topics include thermophysical properties such as heat capacities, phase transformations, multiphase equilibria, chemical reactions, and magnetism; symmetry properties of molecules and solids; and the structure of complex, disordered, and amorphous materials. It also covers tensors and symmetry-imposed constraints on physical properties, as well as structural determination through diffraction techniques. Applications discussed include engineered alloys, electronic and magnetic materials, ionic and network solids, polymers, and biomaterials. |
| Phase Diagrams in Materials Science and Engineering | URL://https://nptel.ac.in/courses/113104068 | Phase diagrams are fundamental to materials science and engineering, with applications spanning structural to functional materials, including |

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| | | electronic and magnetic systems. This course aims to familiarize students and researchers with binary and ternary phase diagrams and the associated microstructures of various materials. Emphasis is placed on understanding the critical role of microstructure in determining material properties and on linking phase diagram information to microstructural evolution. |
| Materials Science | URL://https://nptel.ac.in/courses/112108150 | This course addresses both fundamental and applied aspects of materials science. It encompasses the study of atomic structure, crystalline solids, and defects in materials, alongside the mechanical properties of metals and their strengthening mechanisms. Key topics include diffusion, phase diagrams, material failure, and processing techniques for metals, ceramics, and polymers. Specialized modules cover composites, corrosion, and the electrical, thermal, magnetic, and optical properties of materials. The course concludes with an examination of the economic, environmental, and social implications of material usage. It is designed for engineering students and professionals aiming to deepen their knowledge of materials and their practical applications. |
| Materials Science | URL://https://nptel.ac.in/courses/122102008 | This course covers key aspects of materials science, including crystal structures, lattice defects, phase diagrams, and diffusion mechanisms. It addresses |

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| | | plastic deformation and strengthening mechanisms, phase transformations, with particular emphasis on steel heat treatment, and electrical properties of materials such as conductors, semiconductors, and superconductors. The course is designed for engineering students and professionals. |