

## Bachelor's Track Program: Chemistry and Materials Sciences

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

Winning the Open Doors competition requires a firm grasp of:

- interdisciplinary frameworks integrating chemistry, physics, and mathematics;
- fundamental theoretical principles of the core branches of chemistry—general and inorganic chemistry, physical chemistry, and organic chemistry;
- crystalline structure of matter and the relationship between the structure of substances and materials and their physical, chemical, and functional properties.

The winner is expected to demonstrate a solid command of the following skills:

- applying theoretical knowledge to solving practical problems;
- using interdisciplinary approaches;
- searching, analyzing, and systematizing industry-specific regulatory and technical documentation, peer-reviewed scientific and methodological literature, and other sources via modern libraries and databases.

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

#### 2.1. List of bachelor's degree programs

04.03.01 Chemistry

04.03.02 Chemistry, Physics, and Mechanics of Materials

18.03.01 Chemical Technology

18.03.02 Energy and Resource-Saving Processes in Chemical Engineering, Petrochemistry, and Biotechnology

22.03.01 Materials Science and Materials Technology

### 3. Content

#### Field of science 1. Inorganic and nuclear chemistry

##### Chemistry

1. Atomic structure.
2. Periodic law and Dmitri Mendeleev's periodic system of chemical elements.
3. Electronegativity, valence, and oxidation state.
4. Classification and nomenclature of inorganic substances.
5. Types of chemical bonds; theory of hybridization of atomic orbitals.
6. Chemical reactions; classification of chemical reactions in inorganic chemistry.
7. Theory of electrolytic dissociation; strong and weak electrolytes.
8. Hydrolysis of salts; ionic product of water; hydrogen ion concentration (pH) of solutions.
9. Redox reactions.
10. Chemical properties of elementary substances.
11. Chemical properties of the main classes of inorganic compounds.

#### Field of science 2. Physical chemistry

##### Chemistry and Physics

1. Ideal gas laws; gas density; gas mixtures (Dalton's law); isoprocesses.
2. Chemical equilibrium; factors affecting chemical equilibrium including Le Chatelier's principle; equilibrium constant; calculation of equilibrium constant values.
3. The first law of thermodynamics and its application; enthalpy of formation; Hess's law; thermochemical calculations.
4. Solutions and their classification; factors affecting solubility; methods for expressing solution concentration.

5. Electrochemistry; electrolysis and Faraday's laws; electrochemical series of metal voltages; metal corrosion.
6. Chemical kinetics and catalysis; effects of concentration and temperature on reaction rate; Arrhenius equation; activation energy; methods for determining activation energy.

### **Field of science 3. Analytical chemistry**

#### **Chemistry**

1. Theoretical foundations of analytical chemistry: balancing chemical reaction equations and performing calculations based on them; methods for identifying ions in solution through the formation of precipitates, gases, or colored compounds; conditions for dissolution and precipitation; methods for determining the equivalence point in titrimetric analysis.
2. Major chemical properties of compounds of s-block elements (Na, K, Mg, Ca, Sr, Ba).
3. Major chemical properties of compounds of p-block elements (Al, Si, P, S, Pb, N, Cl).
4. Major chemical properties of compounds of d-block elements (Cr, Mn, Fe, Cu, Zn, Ni).
5. Qualitative analysis of solids and solutions: methods for dissolving solids; classification of ions by analytical groups.
6. Quantitative analysis: gravimetry; titrimetry and its types.

### **Field of science 4. Organic chemistry**

#### **Chemistry**

1. Theoretical foundations of organic chemistry.
2. Saturated hydrocarbons.
3. Unsaturated hydrocarbons.
4. Aromatic hydrocarbons.
5. Oxygen-containing organic compounds.
6. Nitrogen-containing organic compounds.

### **Field of science 5: Chemical technologies and industry**

#### **Chemistry**

1. General scientific principles of chemical production.
2. Raw materials and materials in the chemical industry.
3. Production of sulfuric acid.
4. Production of ammonia.
5. Production of silicate industry products.
6. Production of key organic compounds.
7. Production of high-molecular-weight compounds.

### **Field of science 6: Materials science**

#### **Chemistry and Physics**

1. Crystalline substances and their properties; the concept of symmetry; crystal symmetry classes; categories and crystal systems; types of Bravais lattices.
2. Types of chemical bonds in crystals.
3. Crystalline structure and mechanical and physical properties of metals, ceramics, and polymers.
4. Characteristics of the microstructure of materials; the effect of grain size on the mechanical and physical properties of metals and ceramics.
5. Methods for determining the composition, structure, and properties of materials.

## **4. Preparation materials**

### **4.1. Recommended reading**

**Field of science 1. Inorganic and nuclear chemistry**

Sources in English
Lee J.D. Concise Inorganic Chemistry for JEE (Main & Advanced), 4ed. Chapman & Hall, 1991. 718 p. URL: <a href="https://zlib.pub/book/jd-lee-concise-inorganic-chemistry-for-jee-main-advanced-12ldgeei8s9o">https://zlib.pub/book/jd-lee-concise-inorganic-chemistry-for-jee-main-advanced-12ldgeei8s9o</a>
Miessler Gary L. Inorganic chemistry. Fifth edition., St. Olaf College, Paul J. Fischer, Macalester. College. URL: <a href="https://celqusb.wordpress.com/wp-content/uploads/2017/12/inorganic-chemistry-g-l-miessler-2014.pdf">https://celqusb.wordpress.com/wp-content/uploads/2017/12/inorganic-chemistry-g-l-miessler-2014.pdf</a>
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: <a href="https://zlib.pub/book/inorganic-chemistry-71ndlsulje40">https://zlib.pub/book/inorganic-chemistry-71ndlsulje40</a>

**Field of science 2. Physical chemistry**

Sources in English
Burrows A., Holman J., Lancaster S., Overton T., Parsons A., Pilling G., Price G. Chemistry <sup>3</sup> . Oxford university press. 2021. 1440 p. URL: <a href="https://global.oup.com/ukhe/product/chemistry-9780198829980?cc=ru&amp;lang=en">https://global.oup.com/ukhe/product/chemistry-9780198829980?cc=ru&amp;lang=en</a>
Chang R. General chemistry: the essential concepts. 5th ed. NY: McGraw-Hill, 2008. 836 p. URL: <a href="https://chemistry.com.pk/books/chang-general-chemistry/">https://chemistry.com.pk/books/chang-general-chemistry/</a>
Ebbing D.D. Gammon S. D. General Chemistry. U.S.A.: Houghton mifflin company, 2016, 864 p. URL: <a href="https://zlib.pub/book/general-chemistry-686600il1qn0">https://zlib.pub/book/general-chemistry-686600il1qn0</a>
Solovyeva G.V. General Chemistry. Basic level. Ekaterinburg. Ural University Publishing House, 2017. — 182 p. URL: <a href="http://elar.urfu.ru/handle/10995/46981">http://elar.urfu.ru/handle/10995/46981</a>

**Field of science 3. Analytical chemistry**

Sources in English
Greenwood N.N., Earnshaw A. Chemistry of elements. Oxford: elsevir, 1998. 1376 p. URL: <a href="http://lib.ysu.am/disciplines_bk/931545868d143aa17a18c4ad33a7ea3e.pdf">http://lib.ysu.am/disciplines_bk/931545868d143aa17a18c4ad33a7ea3e.pdf</a>
Skoog D.A., West D.M., Holler J. Fundamentals of Analytical Chemistry, Ninth edition. Belmont: Cengage Learning, 2013. 1072 p. URL: <a href="https://tech.chemistrydocs.com/Books/Analytical/Fundamentals-of-Analytical-Chemistry-by-Douglas-A.-Skoog-9th-Ed.pdf">https://tech.chemistrydocs.com/Books/Analytical/Fundamentals-of-Analytical-Chemistry-by-Douglas-A.-Skoog-9th-Ed.pdf</a>
Vogel A.I., Svehla G. Textbook of Macro and Semimicro Qualitative Inorganic Analysis. Michigan: Longman Scientific & Technical, 1987. 310 p. URL: <a href="https://kresnadipayana.wordpress.com/wp-content/uploads/2018/10/macro-and-semimicro-qualitative-inorganic-analysis-5ed-vogel.pdf">https://kresnadipayana.wordpress.com/wp-content/uploads/2018/10/macro-and-semimicro-qualitative-inorganic-analysis-5ed-vogel.pdf</a>

**Field of science 4. Organic chemistry**

Sources in English
Clayden J., Greeves N., Warren S. Organic Chemistry. Oxford university press, 2012. URL: <a href="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">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</a>
Graham Solomons T.W. Organic chemistry. Hoboken, NJ: John Wiley & Sons, 2016. 1293 p.

URL: <a href="https://dl.iranchembook.ir/ebook/organic-chemistry-2808.pdf">https://dl.iranchembook.ir/ebook/organic-chemistry-2808.pdf</a>
McMurry J. Fundamentals of organic chemistry. Belmont: Cengage Learning, 2011. 677 p. URL: <a href="https://tech.chemistrydocs.com/Books/Organic/Fundamentals-of-Organic-Chemistry-by-John-McMurry-7th-Edition.pdf">https://tech.chemistrydocs.com/Books/Organic/Fundamentals-of-Organic-Chemistry-by-John-McMurry-7th-Edition.pdf</a>

### Field of science 5. Chemical technologies and industry

Sources in English
Katarzyna Staszak, Karolina Wieszczycka, Bartosz Tylkowski Chemical Technologies and Processes. Publisher: De Gruyter. 2020. 301p. URL: <a href="https://www.researchgate.net/publication/342819475_Chemical_Technologies_and_Processes">https://www.researchgate.net/publication/342819475_Chemical_Technologies_and_Processes</a>
Moulijn J.A., Makkee V., Vandepen A.E. Chemical Process Technology 013 John Wiley & Sons Ltd 567p. URL: <a href="https://students.aiu.edu/submissions/profiles/resources/onlineBook/S8k7w4_Chemical_Process_Technology_2nd_Edition.pdf">https://students.aiu.edu/submissions/profiles/resources/onlineBook/S8k7w4_Chemical_Process_Technology_2nd_Edition.pdf</a>
Skogestad S. Chemical and Energy Process Engineering CRC Press (2008/2009). 450 p. URL: <a href="https://skoge.folk.ntnu.no/book-cep/sample/bok_English_all1_final.pdf">https://skoge.folk.ntnu.no/book-cep/sample/bok_English_all1_final.pdf</a>

### Field of science 6. Materials science

Sources in English
Malgrange C., Ricolleau C., Schlenker M. Symmetry and Physical Properties of Crystals, Springer, 2011. 536p URL: <a href="https://reallib.org/reader?file=2243578&amp;pg=531">https://reallib.org/reader?file=2243578&amp;pg=531</a>
Materials Science and Technology. Edited by Sabar D. Published by InTech, 2012. 336 p. URL: <a href="http://www.issp.ac.ru/ebooks/books/open/Materials_Science_and_Technology.pdf">http://www.issp.ac.ru/ebooks/books/open/Materials_Science_and_Technology.pdf</a>
Anderson J.C., Leaver K.D., Leever P., Rawlings R.D. Materials Science for Engineers. Nelson Thornes Ltd. 2003. 908 p. URL: <a href="https://students.aiu.edu/submissions/profiles/resources/onlineBook/g8K6V5_Materials_Science_for_Engineers.pdf">https://students.aiu.edu/submissions/profiles/resources/onlineBook/g8K6V5_Materials_Science_for_Engineers.pdf</a>

## 4.2. Recommended online courses

### Field of science 1. Inorganic and nuclear chemistry

Online courses in English	Link	Course description
General Inorganic Chemistry	URL: <a href="https://www.alphaacademy.org/course/general-inorganic-chemistry/">https://www.alphaacademy.org/course/general-inorganic-chemistry/</a>	This course provides a comprehensive introduction to the fundamental principles of inorganic chemistry. Covering topics from atomic structure to complex chemical reactions, it establishes a solid foundation for further study in chemistry. Participants gain a thorough understanding of chemical bonding, thermodynamics, and electrochemistry, with practical applications across scientific and industrial fields.
General Chemistry I Online Course	URL: <a href="https://und.edu/academics/online/enroll-anytime/chem121.html">https://und.edu/academics/online/enroll-anytime/chem121.html</a>	This course covers fundamental principles and theories of chemistry, including matter, measurement, atoms, ions, molecules, reactions, chemical calculations, thermochemistry, communication, molecular geometry, periodicity, and gases.
General chemistry	URL: <a href="https://ecampus.oregonstate.edu/online-degrees/undergraduate/online-general-chemistry/">https://ecampus.oregonstate.edu/online-degrees/undergraduate/online-general-chemistry/</a>	This course addresses the core thematic areas of general and inorganic chemistry.

### Field of science 2. Physical chemistry

Online courses in English	Link	Course description
Introduction to Physical Chemistry	URL: <a href="https://alison.com/course/introduction-to-physical-chemistry">https://alison.com/course/introduction-to-physical-chemistry</a>	This course explores key concepts in major areas of physical chemistry, including thermodynamics and chemical kinetics.
Physical chemistry	URL: <a href="https://www.youtube.com/watch?v=PQechXuFoyI&amp;ab_channel=AcademicLesson">https://www.youtube.com/watch?v=PQechXuFoyI&amp;ab_channel=AcademicLesson</a>	This lecture course presents the principal thematic areas within the field of physical chemistry.
General Chemistry: Development and Application of Concepts	URL: <a href="https://www.coursera.org/learn/general-chemistry#recommendations">https://www.coursera.org/learn/general-chemistry#recommendations</a>	The course covers topics such as phase transitions and equilibria, gas laws, kinetic theory of gases, chemical kinetics, chemical thermodynamics, and chemical equilibrium.
Electrochemistry	URL: <a href="https://www.classcentral.com/course/chemistry-harvard-university-">https://www.classcentral.com/course/chemistry-harvard-university-</a>	This course covers key concepts of acid-base reactions and their connection to chemical equilibrium, as well as the relationship among electrical, chemical,

	<a href="#">electrochemistry-61436</a>	and mechanical energy.
--	--	------------------------

### Field of science 3. Analytical chemistry

Online courses in English	Link	Course description
Basic analytical chemistry (EDX)	URL: <a href="https://www.edx.org/learn/chemistry/the-university-of-tokyo-basic-analytical-chemistry">https://www.edx.org/learn/chemistry/the-university-of-tokyo-basic-analytical-chemistry</a>	This course introduces the principles of analytical chemistry and explores their applications in chemistry and related fields, particularly in the life sciences, environmental sciences, and geochemistry.
Analytical chemistry (Alison)	URL: <a href="https://alison.com/tag/analytical-chemistry">https://alison.com/tag/analytical-chemistry</a>	This course in analytical chemistry introduces methods for identifying and quantifying substances. It presents a range of tools and techniques for separation, identification, quantification, and analysis, including classical wet chemistry methods and modern instrumental approaches.
Inorganic chemistry (Alison)	URL: <a href="https://alison.com/tag/inorganic-chemistry">https://alison.com/tag/inorganic-chemistry</a>	This course covers the properties, characteristics, and reactions of elements, metals, alloys, salts, complexes, acids, and other non-carbon substances.

### Field of science 4. Organic chemistry

Online courses in English	Link	Course description
Organic chemistry (EDX)	URL: <a href="https://www.edx.org/learn/organic-chemistry">https://www.edx.org/learn/organic-chemistry</a>	This course focuses on the study of organic compounds—substances containing one or more carbon atoms. It introduces fundamental topics, including types of organic reactions, molecular structures, alkanes, cycloalkanes, alkenes, alkynes, amino acids, peptides, proteins, nucleotides, and nucleic acids.
Organic chemistry (Khan Academy)	URL: <a href="https://www.khanacademy.org/science/organic-chemistry">https://www.khanacademy.org/science/organic-chemistry</a>	This organic chemistry course examines the reactions chemists use to synthesize carbon-based structures and the analytical methods employed to characterize them. It also explores reaction mechanisms to understand how these processes occur at the molecular level.
Foundations of organic chemistry (Classcentral)	URL: <a href="https://www.classcentral.com/course/the-great-courses-plus-foundations-of-organic-chemistry-131481">https://www.classcentral.com/course/the-great-courses-plus-foundations-of-organic-chemistry-131481</a>	This course presents the main classes of organic compounds and their properties.

### Field of science 5. Chemical technologies and industry

Online courses in English	Link	Course description
Chemical Engineering Fundamentals	URL: <a href="https://www.classcentral.com/course/udemy-chemical-engineering-fundamentals-69910">https://www.classcentral.com/course/udemy-chemical-engineering-fundamentals-69910</a>	This course explores fundamental chemical engineering concepts, including process flow diagrams, mixture properties, and mass and energy balances.
Chemical Engineering Thermodynamics 1	URL: <a href="https://www.classcentral.com/course/chemtherm1-145866">https://www.classcentral.com/course/chemtherm1-145866</a>	This course explores the fundamental principles of thermodynamics and their applications in engineering.
Chemical Engineering Overview	URL: <a href="https://alison.com/course/chemical-engineering-overview">https://alison.com/course/chemical-engineering-overview</a>	This course covers general aspects of chemical technology; fundamental criteria for the efficient use of raw materials and energy resources; material and energy balance equations in technological systems; and key strategies for improving the efficiency of utilizing raw materials and energy resources.

### Field of science 6. Materials science

Online courses in English	Link	Course description
The Fascination of Crystals and Symmetry	URL: <a href="https://iversity.org/en/courses/the-fascination-of-crystals-and-symmetry-2021">https://iversity.org/en/courses/the-fascination-of-crystals-and-symmetry-2021</a>	This course covers the fundamental building blocks of crystals, their symmetrical structures, and introduces free software for studying crystal structures. It offers foundational knowledge of crystallography, emphasizing the symmetry elements found in crystals.
Chemical Crystallography	URL: <a href="https://www.nptel.ac.in/courses/6.00/2019Fall/lec01.html">https://www.nptel.ac.in/courses/6.00/2019Fall/lec01.html</a> <a href="https://onlinecourses.nptel.ac.in/noc19_cy35/preview">https://onlinecourses.nptel.ac.in/noc19_cy35/preview</a>	This course, designed for experimental and inorganic chemists, covers the concepts and applications of X-ray crystallography. It guides students through crystallographic symmetry, structure determination, and the refinement of crystal structures using X-ray diffraction.
Mechanical Properties Definitions {Texas A&M: Intro to Materials}	URL: <a href="https://www.youtube.com/watch?v=1UbO7UxvPBc">https://www.youtube.com/watch?v=1UbO7UxvPBc</a>	This video course offers an introduction to materials science and engineering, emphasizing the mechanical properties of materials