Program: Chemistry and Materials Science

This document outlines the scope of themes, which may be included in the Olympiad tests. The themes are grouped by areas and are followed by the list of recommended references in the Russian and English languages.

Olympiad winner's skill set by Subject

To complete the tasks of the Olympiad, you must:
- know the basics of general, inorganic, and organic chemistry, chemical thermodynamics, kinetics and theory of solutions, theory of phase equilibria, and materials science;
- be able to apply the acquired knowledge to solve chemical tasks, find and analyze the necessary data, choose and apply adequate research methods, as well as analyze the obtained results.

Content

Section 1. General and inorganic chemistry

1. Main types of chemical bonds and the geometry of polyatomic molecules
2. Acid-base balance. Solutions of strong electrolytes
3. Heterogeneous equilibria in the system of solid state: solutions for insoluble electrolytes
4. Redox equation. Standard, real, and formal redox potentials
5. Structure and isomerism of coordination compound, equilibria in solutions of coordination compounds
6. Typical valences, degrees of oxidation, resultant compounds, their physical and chemical properties, industrial applications

Section 2. Physical chemistry

1. The first law of thermodynamics and its application (internal energy, enthalpy, heat and work, equilibrium and non-equilibrium processes)
2. Thermochemistry. Hess's law, the Kirchhoff equation
3. The second law of thermodynamics (entropy, thermodynamic potentials, and characteristic functions)
4. The Gibbs fundamental equation, the Gibbs-Helmholtz equations, the third law of thermodynamics (the Nernst heat theorem), the Planck postulate, chemical potential
5. Phase equilibria: heterogeneous systems, the Gibbs phase rule, the Clausius-Clapeyron equation
6. Phase diagrams, properties of solutions
7. Surface phenomena, thermodynamics of surface phenomena, adsorption. Gibbs and Langmuir's isotherm adsorption
8. Thermodynamics of electrochemical systems: electrochemical potential and equilibrium conditions, the EMF of an electrochemical cell, electrode potential, the Nernst equation
9. The electrical conductivity of electrolyte solutions, ion mobility and transport numbers, the Debye–Hückel theory
10. Chemical kinetics and catalysis: the effect of temperature on the reaction rate, the Arrhenius equation, activation energy, methods to determine activation energy
11. Chemical equilibria: the law of mass action and the equilibrium constant, the isotherm equation, the isobaric and isochoric processes of a chemical reaction

Section 3. Organic chemistry

1. The structure of organic molecules: the nature of the chemical bond, the distribution of electron density in a molecule, types of isomerism of the organic matter molecule

2. The main classes of organic compounds, the main methods of compound synthesis, and chemical transformation
3. Reaction mechanisms: the electronic and spatial structure of reagents and substrates
4. Natural sources of organic compounds, main methods for the synthesis of key substances, transformations by laboratory and industrial methods
5. The main practical applications of organic compounds
6. Interactions of organic substances with living organisms; the environmental aspects of organic chemical production
7. The basics of molecular spectroscopy (IR, UV, NMR), mass spectrometry, and X-ray diffraction

Section 4. Solid-state chemistry

1. The structure of periodic crystals: basic principles. Symmetry elements and symmetry operations, the choice of a unit cell, point and space symmetry groups, close-packed structures, and coordination polyhedra in the crystal structure description, polymorphism
2. Point defects in crystals and the relationship between the concentration of impurities and intrinsic point defects, nonstoichiometry, and the environment of the sample
3. Extended defects: dislocations, disclinations, and packing defects. The interaction between point and extended defects
4. First-order phase transitions and second-order phase transitions, the Gibbs phase rule, the dissolution-crystallization curve, metastable crystallization zone
5. The molecular kinetic theory of crystal growth (the Kossel-Stranski model, the Bravais law, the Wulff construction, types of crystal growth, epitaxial growth of crystals, crystal twinning)
6. Properties of solids and their relationship with the crystal bulk and surface structure; the presence, type, and concentration of defects and the size and shape of particles
7. The electronic structure of solids: band theory, metals, semiconductors, and insulators, electron and hole conductivity

Section 5. Materials science

1. Crystal structure, mechanical and physical properties of metals, ceramics, and polymers
2. Characteristics of a microstructure of materials, the influence of crystallite size on the mechanical and physical properties of metals and ceramics (the Hall-Petch relationship)
3. Composite materials: structure and mechanical properties, metal hardening mechanisms, combinations of hardening mechanisms in composites with metal matrices, the rule of mixtures in calculating the mechanical and physical characteristics of composites
4. Solid solutions: types and structures; Vegard's law for solid solutions, alloys, and intermetallic compounds
5. Stress-strain (σ–ε) curve for solids (flow stress, yield stress, and ultimate tensile strength)
6. Fatigue of materials: fatigue limit, the characteristics of the cyclic stress-strain response, the fatigue curve
7. The Fe-C diagram (transformations in steels; the structure and properties of steels)

Recommended literature

Section 1. General and inorganic chemistry

Sources	Topic
1. Fetisova A., A. Svistunov, T. Litvinova. Fundamentals of terminology, reading, interpreting and solving problems in chemistry in English. General Chemistry. Advanced Level. Textbook.	2) Acid-base balance, solutions of strong and weak electrolytes

I.M. Sechenov First Moscow State Medical University. - Moscow, 2016. URL://https://profil.mos.ru/images/docs/05_02_2016/med/metodichki/uch_pos_himia_na_englisn.pdf (free access)	
2. Greenwood N.N. and Earnshaw A. Chemistry of the elements. Butterworth-Heinemann, 1997. URL:// https://www.elsevier.com/books/chemistry-of-the-elements/greenwood/978-0-7506-3365-9 (limited access)	6) Typical valences, degrees of oxidation, resultant compounds, their physical and chemical properties, industrial applications
3. Hoffmann R. Solids and surfaces: a chemist's view of bonding in extended structures. 1st edition. Wiley-VCH, 1991. 152 p. URL://https://www.wiley.com/en-us/Solids+and+Surfaces:+A+Chemist's+View+of+Bonding+in+Extended+Structures-p-9780471187103 (limited access)	1) Main types of chemical bonds and geometry of polyatomic molecules
4. Lefrou C., Fabry P., Poignet J. C. Electrochemistry: the basics, with examples. – Springer Science & Business Media, 2012 URL://https://www.researchgate.net/publication/292359282_Electrochemistry_The_basics_with_examples (limited access)	2) Acid-base balance, solutions of strong and weak electrolytes 3) Heterogeneous equilibria in the system of solid state: solutions for insoluble electrolytes
5. Petrucci Ralph H., Herring F. Geoffrey, Madura Jeffry D., Bissonnette Carey. General Chemistry: Principles and Modern Applications — 11th Edition. — Toronto : Pearson, 2017. 1496 p. URL://https://chemistry.com.pk/books/general-chemistry-11e-petrucci-herring/ (limited access)	4) Redox equation, standard, real, and formal redox potentials 5) Structure and isomerism of coordination compounds, equilibria in solutions of coordination compounds
6. Ахметов Н.С. Общая и неорганическая химия. Учеб.для вузов. М.: Изд. Центр «Академия», 2001. 743 с. URL:// https://vk.com/wall-120203091_13270 (free access) URL:// https://pdf.11klasov.net/17157-obschaja-i-neorganicheskaja-himija-ahmetov-ns.html (free access)	1) Main types of chemical bonds and geometry of polyatomic molecules 3) Heterogeneous equilibria in the system of solid state: solutions for insoluble electrolytes 6) Typical valences, degrees of oxidation, resultant compounds, their physical and chemical properties, industrial applications
7. Под ред. В.А. Попкова, А.В. Бабкова. Глинка Н.Л. Общая химия. М.: Юрайт, 2016. 364 с. URL://http://lib.sibsport.ru/www/libsport.nsf/0/2c7a3df5e57b9695472581a60032eb77/$FILE/Глинка_1.pdf (free access)	2) Acid-base balance, solutions of strong and weak electrolytes 3) Heterogeneous equilibria in the system of solid state: solutions for insoluble electrolytes 6) Typical valences, degrees of oxidation, resultant compounds, their

	physical and chemical properties, industrial applications

Section 2. Physical chemistry

Sources	Topic
1. G. Job and R. Rüffler, Physical Chemistry from a Different Angle Workbook. Springer Cham, 2019. 291 p. URL://https://doi.org/10.1007/978-3-030-28491-6 (limited access)	8) Thermodynamics of electrochemical systems: electrochemical potential and equilibrium conditions, the EMF of an electrochemical cell, electrode potential, the Nernst equation 9) The electrical conductivity of electrolyte solutions, ion mobility and transport numbers, the Debye–Hückel theory 10) Chemical kinetics and catalysis: the effect of temperature on the reaction rate, the Arrhenius equation, activation energy, methods to determine activation energy
2. Hibbert, D. B. Introduction to electrochemistry. MacMillan Basingstoke, 1993. 350 p. URL://https://nla.gov.au/nla.cat-vn2761535 (limited access)	8) Thermodynamics of electrochemical systems: electrochemical potential and equilibrium conditions, the EMF of an electrochemical cell, electrode potential, the Nernst equation 9) The electrical conductivity of electrolyte solutions, ion mobility and transport numbers, the Debye–Hückel theory
3. Hofmann, A. Physical Chemistry Essentials. // Physico-chemical Data and Resources, Springer, Cham., 2018. pp.1-11. URL://https://doi.org/10.1007/978-3-319-74167-3_1 (limited access)	1) The first law of thermodynamics and its application (internal energy, enthalpy, heat and work, equilibrium and non-equilibrium processes). 2)Thermochemistry, Hess's law, the Kirchhoff equation. 3) The second law of thermodynamics (entropy, thermodynamic potentials, and characteristic functions) 4) The Gibbs fundamental equation, the Gibbs-Helmholtz equations, the third law of thermodynamics (the Nernst heat theorem), the Planck postulate, chemical potential 5) Phase equilibria: heterogeneous systems, the Gibbs phase rule, the Clausius-Clapeyron equation 6) Phase diagrams, properties of solutions

	8) Thermodynamics of electrochemical systems: electrochemical potential and equilibrium conditions, the EMF of an electrochemical cell, electrode potential, the Nernst equation 9) The electrical conductivity of electrolyte solutions, ion mobility and transport numbers, the Debye–Hückel theory 10) Chemical kinetics and catalysis: the effect of temperature on the reaction rate, the Arrhenius equation, activation energy, methods to determine activation energy 11) Chemical equilibria: the law of mass action and the equilibrium constant, the isotherm equation, the isobaric and isochoric processes of a chemical reaction
4. Keszei, E. Chemical Thermodynamics. Springer Berlin Heidelberg, 2012. 354 p. URL://https://doi.org/10.1007/978-3-642-19864-9 (limited access)	1) The first law of thermodynamics and its application (internal energy, enthalpy, heat and work, equilibrium and non-equilibrium processes) 2) Thermochemistry, Hess's law, the Kirchhoff equation 3) The second law of thermodynamics (entropy, thermodynamic potentials, and characteristic functions) 4) The Gibbs fundamental equation, the Gibbs-Helmholtz equations, the third law of thermodynamics (the Nernst heat theorem), the Planck postulate, chemical potential
5. Mário J. de Oliveira Equilibrium Thermodynamics. Springer Berlin, Heidelberg, 2017. 400 p. URL://https://doi.org/10.1007/978-3-662-53207-2 (limited access)	5) Phase equilibria: heterogeneous systems, the Gibbs phase rule, the Clausius-Clapeyron equation 6) Phase diagrams, properties of solutions 11) Chemical equilibria: the law of mass action and the equilibrium constant, isotherm equation, isobaric and isochoric processes of chemical reaction

6. Pashley Richard M., Karaman Marilyn E. Applied Colloid and Surface Chemistry, 2nd Edition. John Wiley & Sons, 2021. 256 p. URL://https://books.google.ru/books/about/Applied_Colloid_and_Surface_Chemistry.html?id=yNU7EAAAQBAJ&redir_esc=y (limited access)	7) Surface phenomena, thermodynamics of surface phenomena, adsorption, Gibbs and Langmuir's isotherm adsorption
7. Shchukin, E.D., Pertsov, A.V., Amelina, E.A., Zelenev, A.S. Colloid and Surface Chemistry. 1st Edition. Elsevier Science, 2001. 774 p. URL://https://www.elsevier.com/books/colloid-and-surface-chemistry/shchukin/978-0-444-50045-8 (limited access)	7) Surface phenomena, thermodynamics of surface phenomena, adsorption, Gibbs and Langmuir's isotherm adsorption
8. Smith, E. Brian. Basic chemical thermodynamics. Oxford: Clarendon Press, 1977. 132 p. URL://https://nla.gov.au/nla.cat-vn2516889 (limited access)	1) The first law of thermodynamics and its application (internal energy, enthalpy, heat and work, equilibrium and non-equilibrium processes). 2) Thermochemistry, Hess's law, the Kirchhoff equation. 3) The second law of thermodynamics (entropy, thermodynamic potentials, and characteristic functions). 4) The Gibbs fundamental equation, Gibbs-Helmholtz equations, the third law of thermodynamics (the Nernst heat theorem), Planck postulate, chemical potential
9. Soustelle, M. An Introduction to Chemical Kinetics. Wiley Online Library, 2011. 448 p. URL://https://doi.org/10.1002/9781118604243 (limited access)	10) Chemical kinetics and catalysis: the effect of temperature on the reaction rate, the Arrhenius equation, activation energy, methods of its determination
10. Stanley M. Walas. Phase Equilibria in Chemical Engineering. Butterworth-Heinemann, 1985. 688 p. URL://https://www.elsevier.com/books/phase-equilibria-in-chemical-engineering/walas/978-0-409-95162-2 (limited access)	5) Phase equilibria: heterogeneous systems, Gibbs phase rule, the Clausius-Clapeyron equation. 6) Phase diagrams, properties of solutions 11) Chemical equilibria: the law of mass action and the equilibrium constant, the isotherm equation, the isobaric and isochoric processes of a chemical reaction

Section 3. Organic chemistry

Sources	**Topic**
1. Clayden, Greeves, Warren. Organic Chemistry. Oxford University Press, 2000.	1) The structure of organic molecules: the nature of the chemical bond, the

Sources	Topic
https://www.academia.edu/35755359/Organic_Chemistry_By_Clayden_Greeves_Warren_and_Wothers (limited access)	distribution of electron density in a molecule, types of isomerism of the organic matter molecule 2) The main classes of organic compounds, the main methods of compound synthesis, and chemical transformation 3) Reaction mechanisms: the electronic and spatial structure of reagents and substrates
2. Hart H. "Organic Chemistry – A Short Course". Hart H., Habad C.M.,Craine L.E., Hart D.J. – 13th edition. – Cengage Learning, 2011. 600 p. URL:// https://archive.org/details/organicchemistry0000hart_p9s2/page/n5/mode/2up (free access)	1) The structure of organic molecules: the nature of the chemical bond, the distribution of electron density in a molecule, types of isomerism of the organic matter molecule 2) The main classes of organic compounds, the main methods of compound synthesis, and chemical transformation 3) Reaction mechanisms: the electronic and spatial structure of reagents and substrates
3. Jerry, M. Advanced Organic Chemistry: Reactions, Mechanisms, and Structure (6th ed.), New York: Wiley-Interscience, 2007. 1376 p. URL://https://archive.org/details/advancedorganicc0000marc/page/n5/mode/2up (free access)	1) The structure of organic molecules: the nature of the chemical bond, the distribution of electron density in a molecule, types of isomerism of the organic matter molecule 2) The main classes of organic compounds, the main methods of compound synthesis, and chemical transformation 3) Reaction mechanisms: the electronic and spatial structure of reagents and substrates 4) Natural sources of organic compounds, main methods for the synthesis of key substances, transformations by laboratory and industrial methods 5) The main practical applications of organic compounds 6) Interactions of organic substances with living organisms; the environmental aspects of organic chemical production 7) The basics of molecular spectroscopy (IR, UV, NMR), mass spectrometry, and X-ray diffraction

Sources	Topic
4. Органическая химия. Учебник. Под ред. Н.А. Тюкавкиной. М.: Дрофа, 2003. 640 с. URL:// https://pdf.11klasov.net/8017-organicheskaja-himija-v-2-kn-pod-redakciej-tjukavkinoj-na.html (free access)	1) The structure of organic molecules: the nature of the chemical bond, the distribution of electron density in a molecule, types of isomerism of the organic matter molecule 2) The main classes of organic compounds, the main methods of compound synthesis, and chemical transformation 3) Reaction mechanisms: the electronic and spatial structure of reagents and substrates 4) Natural sources of organic compounds, main methods for the synthesis of key substances, transformations by laboratory and industrial methods 5) The main practical applications of organic compounds 6) Interactions of organic substances with living organisms; the environmental aspects of organic chemical production 7) The basics of molecular spectroscopy (IR, UV, NMR), mass spectrometry, and X-ray diffraction

Section 4. Solid-state chemistry

Sources	Topic
1. Cowley John M. Diffraction physics. 1975 URL://https://booksee.org/book/450895 (free access)	1) The structure of periodic crystals: basic principles. Symmetry elements and symmetry operations, the choice of a unit cell, point and space symmetry groups, close-packed structures and coordination polyhedra in the crystal structure description, polymorphism 2) Point defects in crystals and the relationship between the concentration of impurities and intrinsic point defects, nonstoichiometry, and the environment of the sample 3) Extended defects: dislocations, disclinations, and packing defects. The interaction between point and extended defects 4) First-order phase transitions and second-order phase transitions, the Gibbs phase rule, the dissolution-crystallization curve, metastable crystallization zone 5) The molecular kinetic theory of crystal growth (the Kossel-Stranski model, the Bravais law, the Wulff construction, types of

	crystal growth, epitaxial growth of crystals, crystal twinning)
2. De Graef M. McHenry Michael E. Structure of Materials. An Introduction to Crystallography, Diffraction and Symmetry. Cambridge University Press, 2012 URL://https://assets.cambridge.org/97811070/05877/frontmatter/9781107005877_frontmatter.pdf (limited access)	1) The structure of periodic crystals: basic principles. Symmetry elements and symmetry operations, the choice of a unit cell, point and space symmetry groups, close-packed structures and coordination polyhedra in the crystal structure description, polymorphism 2) Point defects in crystals and the relationship between the concentration of impurities and intrinsic point defects, nonstoichiometry, and the environment of the sample 3) Extended defects: dislocations, disclinations, and packing defects. The interaction between point and extended defects 4) First-order phase transitions and second-order phase transitions, the Gibbs phase rule, the dissolution-crystallization curve, metastable crystallization zone 5) The molecular kinetic theory of crystal growth (the Kossel-Stranski model, the Bravais law, the Wulff construction, types of crystal growth, epitaxial growth of crystals, crystal twinning)
3. Jones David R. H., Ashby Michael F. Engineering Materials 1: An Introduction to Properties, Applications and Design. 5th Edition, Kindle Edition URL://https://www.researchgate.net/file.PostFileLoader.html?id=57a0a9d3f7b67e46596ee22b&assetKey=AS%3A390639096221699%401470147027040 (free access)	6) Properties of solids and their relationship with the crystal bulk and surface structure; the presence, type, and concentration of defects; the size and shape of particles 7) The electronic structure of solids: band theory, metals, semiconductors, and insulators, electron and hole conductivity
4. Neil W., Ashcroft N., David Mermin. Solid state physics, 2000 URL://https://en.bookfi.net/book/1422363 (free access)	6) Properties of solids and their relationship with the crystal bulk and surface structure; the presence, type, and concentration of defects; the size and shape of particles 7) The electronic structure of solids: band theory, metals, semiconductors, and insulators, electron and hole conductivity
5. Горелик С.С., Дашевский М.Я. Материаловедение полупроводников и диэлектриков, Учебник для вузов, 2003. 480 с. URL://https://booksee.org/book/635301 (free access)	6) Properties of solids and their relationship with the crystal bulk and surface structure; the presence, type, and concentration of defects; the size and shape of particles 7) The electronic structure of solids: band theory, metals, semiconductors, and insulators, electron and hole conductivity
6. Егоров-Тисменко Ю.К. Кристаллография и кристаллохимия. М.:	1) The structure of periodic crystals: basic principles. Symmetry elements and symmetry

КДУ, 2005. 589 с. URL://https://www.geokniga.org/bookfiles/geokniga-kristallografiya-i-kristallohimiya-egorov-tismenko-yuk-2005.pdf (free access)	operations, the choice of a unit cell, point and space symmetry groups, close-packed structures and coordination polyhedra in the crystal structure description, polymorphism 2) Point defects in crystals and the relationship between the concentration of impurities and intrinsic point defects, nonstoichiometry, and the environment of the sample 3) Extended defects: dislocations, disclinations, and packing defects. The interaction between point and extended defects 4) First-order phase transitions and second-order phase transitions, the Gibbs phase rule, the dissolution-crystallization curve, metastable crystallization zone 5) The molecular kinetic theory of crystal growth (the Kossel-Stranski model, the Bravais law, the Wulff construction, types of crystal growth, epitaxial growth of crystals, crystal twinning)
7. Китайгородский А.И. Рентгеноструктурный анализ. 1950. - 651 с. URL://https://lib-bkm.ru/14378 (free access)	1) The structure of periodic crystals: basic principles. Symmetry elements and symmetry operations, the choice of a unit cell, point and space symmetry groups, close-packed structures and coordination polyhedra in the crystal structure description, polymorphism 2) Point defects in crystals and the relationship between the concentration of impurities and intrinsic point defects, nonstoichiometry, and the environment of the sample 3) Extended defects: dislocations, disclinations, and packing defects. The interaction between point and extended defects
8. Розин К.М. Практическая кристаллография. М.:МИСиС, 2005, 168 с. URL://https://www.geokniga.org/bookfiles/geokniga-prakticheskoe-rukovodstvo-po-kristallografii-i-kristallohimii-i-metody-opisa.pdf (free access)	1) The structure of periodic crystals: basic principles. Symmetry elements and symmetry operations, the choice of a unit cell, point and space symmetry groups, close-packed structures and coordination polyhedra in the crystal structure description, polymorphism 2) Point defects in crystals and the relationship between the concentration of impurities and intrinsic point defects, nonstoichiometry, and the environment of the sample 3) Extended defects: dislocations, disclinations, and packing defects. The interaction between point and extended defects

9. Шаскольская М.П. Кристаллография. Учеб. пособие для втузов. 2-е изд., перераб. и доп. - М.: Высшая шк. ,1984. - 376 с. URL://https://bookree.org/reader?file=478082 (free access)	1) The structure of periodic crystals: basic principles. Symmetry elements and symmetry operations, the choice of a unit cell, point and space symmetry groups, close-packed structures and coordination polyhedra in the crystal structure description, polymorphism 2) Point defects in crystals and the relationship between the concentration of impurities and intrinsic point defects, nonstoichiometry, and the environment of the sample 3) Extended defects: dislocations, disclinations, and packing defects. The interaction between point and extended defects 4) First-order phase transitions and second-order phase transitions, the Gibbs phase rule, the dissolution-crystallization curve, metastable crystallization zone 5) The molecular kinetic theory of crystal growth (the Kossel-Stranski model, the Bravais law, the Wulff construction, types of crystal growth, epitaxial growth of crystals, crystal twinning)
10. Уманский Я.С., Скаков Ю.А., Иванов А.Н., Расторгуев Л.Н. Кристаллография, рентгенография и электронная микроскопия. М.: Металлургия, 1982 URL://https://booksee.org/book/1215107 (free access)	1) The structure of periodic crystals: basic principles. Symmetry elements and symmetry operations, the choice of a unit cell, point and space symmetry groups, close-packed structures and coordination polyhedra in the crystal structure description, polymorphism 2) Point defects in crystals and the relationship between the concentration of impurities and intrinsic point defects, nonstoichiometry, and the environment of the sample 3) Extended defects: dislocations, disclinations, and packing defects. The interaction between point and extended defects 4) First-order phase transitions and second-order phase transitions, the Gibbs phase rule, the dissolution-crystallization curve, metastable crystallization zone 5) The molecular kinetic theory of crystal growth (the Kossel-Stranski model, the Bravais law, the Wulff construction, types of crystal growth, epitaxial growth of crystals, crystal twinning)
11. Уманский Я.С.,Скаков Ю.А. Физика металлов. Атомное строение металлов и сплавов. Учебник для вузов. М.: Атомиз-дат, 1978	6) Properties of solids and their relationship with the crystal bulk and surface structure; the presence, type, and concentration of defects; the size and shape of particles

URL://https://lib-bkm.ru/load/99-1-0-2713 (free access)	7) The electronic structure of solids: band theory, metals, semiconductors, and insulators, electron and hole conductivity

Section 5. Materials science

Sources	Topic
1. Callister. W.D.Jr., Rethwisch, D.G. Materials Science and Engineering, Wiley, 2014. 1000 p. URL://https://www.researchgate.net/publication/332275311_materials-science-and-engineering-8th-edition-callister (free access)	5) Stress-strain (σ–ε) curve for solids (flow stress, yield stress, and ultimate tensile strength) 6) Fatigue of materials: fatigue limit, the characteristics of the cyclic stress-strain response, the fatigue curve
2. Clyne, T.W., Hull, D. An Introduction to Composite Materials, Cambridge University Press, 2019. 360 p. URL:// (free access)	3) Composite materials: structure and mechanical properties, metal hardening mechanisms, combinations of hardening mechanisms in composites with metal matrices, the rule of mixtures in calculating the mechanical and physical characteristics of composites
3. Huda, Z. Metallurgy for Physicists and Engineers: Fundamentals, Applications, and Calculations. CRC Press, 2020. 381 p. URL://https://ru.zlibrary.org/book/5954360/9aeeed (free access)	1) Crystal structure, mechanical and physical properties of metals, ceramics, and polymers 2) Characteristics of a microstructure of materials, the influence of crystallite size on the mechanical and physical properties of metals and ceramics (the Hall-Petch relationship) 3) Composite materials: structure and mechanical properties, metal hardening mechanisms, combinations of hardening mechanisms in composites with metal matrices, the rule of mixtures in calculating the mechanical and physical characteristics of composites 4) Solid solutions: types and structures; Vegard's law for solid solutions, alloys, and intermetallic compounds 5) Stress-strain (σ–ε) curve for solids (flow stress, yield stress, and ultimate tensile strength) 6) Fatigue of materials: fatigue limit, the characteristics of the cyclic stress-strain response, the fatigue curve
4. Martin, R.M. Electronic Structure: Basic Theory and Practical Methods, Cambridge University Press, 2004. 650 p. URL://https://ru.za1lib.org/book/825641/b5dd96?dsource=recommend (free access)	4) Solid solutions: types and structures; Vegard's law for solid solutions, alloys, and intermetallic compounds

5. O'Hayre, R. Materials Kinetics Fundamentals. Wiley, 2015. 315 p. URL://https://mse.ucf.edu/wp-content/uploads/2020/07/Ryan-O_Hayre-Materials-Kinetics-Fundamentals-Wiley-2015.pdf (free access)	1) Crystal structure, mechanical and physical properties of metals, ceramics, and polymers 2) Characteristics of a microstructure of materials, the influence of crystallite size on the mechanical and physical properties of metals and ceramics (the Hall-Petch relationship)
6. Pennycook, S.J., Nellist, P.D. Scanning Transmission Electron Microscopy: Imaging and Analysis, New York: Springer-Verlag, 2011. 776 p. URL://https://ru.zlibrary.org/book/1059329/af19b4 (free access)	1) Crystal structure, mechanical and physical properties of metals, ceramics, and polymers 2) Characteristics of a microstructure of materials, the influence of crystallite size on the mechanical and physical properties of metals and ceramics (the Hall-Petch relationship)
7. Readey, D.W. Kinetics in Materials Science and Engineering. USA: CRC Press, 2017. 607 p. URL://https://books.google.es/books?id=KRkNDgAAQBAJ&printsec=frontcover&hl=es#v=onepage&q&f=false (свободный доступ) URL://https://ru.vn1lib.org/book/2872037/5095a2 (free access)	1) Crystal structure, mechanical and physical properties of metals, ceramics, and polymers 2) Characteristics of a microstructure of materials, the influence of crystallite size on the mechanical and physical properties of metals and ceramics (the Hall-Petch relationship) 4) Solid solutions: types and structures; Vegard's law for solid solutions, alloys, and intermetallic compounds
8. Singh, S.B., Vakhrushev, A.V., Haghi, A.K. Materials Physics and Chemistry: Applied Mathematics and Chemo-Mechanical Analysis. CRC Press, 2021. 265 p. URL://https://www.researchgate.net/publication/339385559_Materials_Physics_and_Chemistry (limited access)	1) Crystal structure, mechanical and physical properties of metals, ceramics, and polymers 2) Characteristics of a microstructure of materials, the influence of crystallite size on the mechanical and physical properties of metals and ceramics (the Hall-Petch relationship) 3) Composite materials: structure and mechanical properties, metal hardening mechanisms, combinations of hardening mechanisms in composites with metal matrices, the rule of mixtures in calculating the mechanical and physical characteristics of composites 4) Solid solutions: types and structures; Vegard's law for solid solutions, alloys, and intermetallic compounds 5) Stress-strain (σ–ε) curve for solids (flow stress, yield stress, and ultimate tensile strength) 6) Fatigue of materials: fatigue limit, the characteristics of the cyclic stress-strain response, the fatigue curve

9. Turilina V. Material science: mechanical properties of metals. Heat treatment of metals. Special steels and alloys: textbook. M.: Publishing House "MISiS", 2013. – 154 p. URL:// https://avidreaders.ru/read-book/materialovedenie-mehanicheskie-svoystva-metallov-termicheskaya-obrabotka.html (limited access)	1) Crystal structure, mechanical and physical properties of metals, ceramics, and polymers 2) Characteristics of a microstructure of materials, the influence of crystallite size on the mechanical and physical properties of metals and ceramics (the Hall-Petch relationship) 5) Stress-strain (σ–ε) curve for solids (flow stress, yield stress, and ultimate tensile strength) 7) The Fe-C diagram (transformations in steels; the structure and properties of steels)
10. Vollath, D. Nanomaterials: An Introduction to Synthesis, Properties, and Applications. Wiley, 2013. 30 p. URL://https://download.e-bookshelf.de/download/0003/8871/63/L-G-0003887163-0019172335.pdf (free access)	1) Crystal structure, mechanical and physical properties of metals, ceramics, and polymers 2) Characteristics of a microstructure of materials, the influence of crystallite size on the mechanical and physical properties of metals and ceramics (the Hall-Petch relationship)
11. Никулин С., Турилина В. Материаловедение и термическая обработка. Учебное пособие, М. изд. Дом МИСиС, 2013. 171 с. URL:// https://fictionbook.ru/author/sergeyi_nikulin/materialovedenie_i_termicheskaya_obrabotka/ (limited access)	1) Crystal structure, mechanical and physical properties of metals, ceramics, and polymers 2) Characteristics of a microstructure of materials, the influence of crystallite size on the mechanical and physical properties of metals and ceramics (the Hall-Petch relationship) 5) Stress-strain (σ–ε) curve for solids (flow stress, yield stress, and ultimate tensile strength) 7) The Fe-C diagram (transformations in steels; the structure and properties of steels)

Recommended online courses

Section 1. General and inorganic chemistry

1. Fundamentals of General Chemistry (Stepik)
URL:// https://stepik.org/course/4859/promo
2. Fundamentals of General Chemistry (Sechenov.online)
URL:// https://sechenov.online/course?id=203
3. Advanced chemistry (Coursera)
URL:// https://www.coursera.org/learn/advanced-chemistry
4. Chemistry (Coursera)
URL:// https://ru.coursera.org/learn/chemistry-1
5. Introduction to Chemistry: Reactions and Ratios (Coursera)
URL:// https://ru.coursera.org/learn/intro-chemistry
6. General Chemistry: Concept Development and Application (Coursera)
URL:// https://ru.coursera.org/learn/general-chemistry
7. Introduction to Chemistry: Structures and Solutions (Coursera)

URL:// https://ru.coursera.org/learn/basic-chemistry

Section 2. Physical chemistry

1. Patrick J. O'Malley, Michael W. Anderson, Jonathan Agger: Introduction to Physical Chemistry (Coursera)
URL:// https://www.coursera.org/learn/physical-chemistry#instructors.
2. Christopher J. Cramer: Statistical Molecular Thermodynamics (Coursera)
URL:// https://www.coursera.org/learn/statistical-thermodynamics.
3. Rasul Abdullaev, Leonid Braginsky, Arthur Pogosov: Basics of thermodynamics (Coursera) URL:// https://www.coursera.org/learn/thermo-dynamics.
4. Rafael Jaramillo, Jessica Sandland, John Harrold: Thermodynamics of Materials (Coursera) URL:// https://www.edx.org/course/thermodynamics-of-materials-2.
5. Alberto Salleo: Thermodynamics and Phase Equilibria (EDX)
URL:// https://www.edx.org/course/thermodynamics-and-phase-equilibria.
6. Studi live Online Learning. Physical Chemistry - Chemical Thermodynamics Complete Chemistry for Engg and Medical Entrance Exam Preparation. (IIT JEE Main | Advanced | BITSAT | SAT | NEET etc.) (Udemy)
URL:// https://www.udemy.com/share/106CWw/
7. Studi live Online Learning. Physical Chemistry – Electrochemistry. Complete Chemistry for Engg and Medical Entrance Exam Preparation. (IIT JEE Main | Advanced | BITSAT | SAT | NEET etc.) (Udemy)
URL:// https://www.udemy.com/share/106hsK/
8. Elliot Kondor. An Introduction to Chemical Kinetics Introductory Guide to Basic Chemical Kinetics (Udemy)
URL:// https://www.udemy.com/share/102c38/
9. Physical Chemistry: Help & Review (Study.com)
URL:// https://study.com/academy/course/physical-chemistry-help-review.html
10. Free Online Course: Colloids and Surfaces from Swayam (Class Central)
URL:// https://www.classcentral.com/course/swayam-colloids-and-surfaces-19822
11. Физическая химия. Кинетика (Openedu)
URL:// https://openedu.ru/course/misis/CHKIN/
12.Физическая химия. Термодинамика (Openedu)
URL:// https://openedu.ru/course/misis/CHTHER/
13.Физическая химия дисперсных систем (Stepik)
URL:// https://stepik.org/course/Физическая-химия-дисперсных-систем-51631

Section 3. Organic chemistry

1. Organic chemistry (Sechenov.online)
URL:// https://sechenov.online/course?id=350
2. Organic solar cells – Theory and Practice (Coursera)
URL:// https://ru.coursera.org/learn/solar-cell
3. Organic Chemistry (Youtube)
URL:// New Organic Chemistry Playlist - YouTube
4. Crash Course Organic Chemistry (Youtube)
URL:// Crash Course Organic Chemistry Preview - YouTube
5. Alkanes & Alkenes | Organic Chemistry | FuseSchool (Youtube)
URL:// Alkanes & Alkenes | Organic Chemistry | FuseSchool - YouTube
6. Chemicals and Health (Coursera)

URL:// https://ru.coursera.org/learn/chemicals-health

Section 4. Solid-state chemistry

1. Transmission electron microscopy for materials science (Coursera)
URL:// https://www.coursera.org/learn/microscopy
2. Materials Science and Engineering: Crystallography (Udemy)
URL:// https://www.udemy.com/course/crystallography (платный)
3. Fundamentals of Materials Science (Coursera)
URL:// https://www.coursera.org/learn/fundamentals-of-materials-science
4. Microscopy: methods of visualisation in micro- and nano-scale (Stepik)
URL:// https://stepik.org/course/64582/promo
5. Solid State – Chemistry. Crystallography (Udemy)
URL:// https://www.udemy.com/course/solid-state-chemistry/
6. Введение в материаловедение (Openedu)
URL:// https://openedu.ru/course/misis/MATSC1/
7. Современные методы исследования металлических материалов (Openedu)
URL:// https://openedu.ru/course/misis/SMIMM/

Section 5. Materials science

1. Semiconductor Manufacturing (MIT OpenCourseWare)
URL:// https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-780-semiconductor-manufacturing-spring-2003/syllabus/
2. Electrical, Optical & Magnetic Materials and Devices (MIT OpenCourseWare)
URL:// https://ocw.mit.edu/courses/materials-science-and-engineering/3-15-electrical-optical-magnetic-materials-and-devices-fall-2006/
3. Electronic and Mechanical Properties of Materials (MIT OpenCourseWare)
URL:// https://ocw.mit.edu/courses/materials-science-and-engineering/3-225-electronic-and-mechanical-properties-of-materials-fall-2007/
4. Physics for Solid-State Applications (MIT OpenCourseWare)
URL:// https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-730-physics-for-solid-state-applications-spring-2003/
5. Introduction to Nanoelectronics (MIT OpenCourseWare)
URL:// https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-701-introduction-to-nanoelectronics-spring-2010/
6. Submicrometer and Nanometer Technology (MIT OpenCourseWare)
URL:// https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-781j-submicrometer-and-nanometer-technology-spring-2006/
7. Nanotechnology: A Maker's Course (Coursera)
URL:// https://www.coursera.org/learn/nanotechnology