Program: Chemistry & Materials Science

This document outlines the scope of themes that may be included in the Olympiad tests. They are grouped by areas, 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:

- be familiar with the foundations of general, inorganic, analytical, 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 results obtained;
- have the skills to solve theoretical and practical problems, search for information and select correct data, and use adequate methods for analyzing and characterizing substances and materials, as well as for examining and interpreting the results obtained.

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 and weak 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 application

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. Analytical chemistry

1. Theory of strong electrolytes. The total concentration and activity of ions in the solution. The ion activity coefficient and the ionic strength of the solution.
2. Application of the law of acting masses to acid-base equilibria. Buffer solutions. Calculation of pH solutions.
3. Qualitative analysis. Sensitivity of analytical reactions. The main analytical groups of cations and anions.
4. Titrimetric analysis. Methods of expression of concentrations used for calculations in titrimetric analysis. The molar mass of the equivalent. Calculation of the mass of the substance to be determined in the analyzed solution. Direct titration. Substitution titration. Reverse titration.
5. Types of titration. Acid-base titration. Redox titration. Sedimentary titration. Complexometric titration

Section 5. 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 rule, 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. Atkins P.W., Shriver D.F. «Inorganic Chemistry» W. H. Freeman and Company, 2010 – 851p URL://https://archive.org/details/inorganic-chemistry-atkins-shriver-pdf/page/n5/mode/2up (Free access)	1) Main types of chemical bonds and geometry of polyatomic molecules 2) Structure and isomerism of coordination compounds, equilibria in solutions of coordination compounds
2. 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)	1) Redox equation. Standard, real, and formal redox potentials 2) Structure and isomerism of coordination compound, equilibria in solutions of coordination compounds
3. 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 molecule 2) Heterogeneous equilibria in the system of solid state: solutions for insoluble electrolytes 3) Typical valences, degrees of oxidation, resultant compounds, their physical and chemical properties, industrial applications
4. Жмурко Г.П., Казакова Е.Ф., Кузнецов В.Н., Яценко А.В. – Общая химия М.: Издательский дом «Академия», 2011 -512с. URL:// https://chembaby.ru/wp-content/uploads/2017/10/Zhmurko_Obschaya_khimia.pdf (Free access)	1) Main types of chemical bonds and geometry of polyatomic molecules 2) Acid-base balance, solutions of strong and weak electrolytes 3) Redox equation. Standard, real, and formal redox potentials 4) Structure and isomerism of coordination compound, equilibria in solutions of coordination compounds
5. Тамм М.Е., Третьяков Ю.Д. Неорганическая химия. Том 1. М.: Издательский дом «Академия», 2004 -240с. URL://https://cdn.bc-pf.org/resources/chemistry/inorg_chem/Tretyakov_	1) Main types of chemical bonds and geometry of polyatomic molecules 2) Redox equation. Standard, real, and formal redox potentials

neorg_himiya_tom_1.pdf (Free access)	
6. Шевельков А.В., Дроздов А.А., Тамм М.Е. Неорганическая химия. Учебник. М.: Лаборатория знаний, 2021 -586с. URL://https://vk.com/doc257509691_656375317?hash=kNpQKgvaU3MTn8VmI7rKu8WJK9v9qnD39gGHhsZdKBk&dl=AHkqb2hfGditNjeCwnzUwOn8XOQtPMfb437X92Rv3eD (Free access)	1) Structure and isomerism of coordination compound, equilibria in solutions of coordination compounds

Section 2. Physical chemistry

Sources	**Topic**
1. Job G. and 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 (Limited access)	1) Thermodynamics of electrochemical systems: electrochemical potential and equilibrium conditions, the EMF of an electrochemical cell, electrode potential, the Nernst equation 2) The electrical conductivity of electrolyte solutions, ion mobility and transport numbers, the Debye–Hückel theory 3) Chemical kinetics and catalysis: the effect of temperature on the reaction rate, the Arrhenius equation, activation energy, methods to determine activation energy
2. 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
3. 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
4. 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)	1) Phase equilibria: heterogeneous systems, the Gibbs phase rule, the Clausius-Clapeyron equation 2) Phase diagrams, properties of solutions 3) Chemical equilibria: the law of mass action and the equilibrium constant, isotherm equation, isobaric and isochoric processes of chemical reaction
5. 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)	1) Surface phenomena, thermodynamics of surface phenomena, adsorption. Gibbs and Langmuir's isotherm adsorption
6. Shchukin, E.D., Pertsov, A.V., Amelina, E.A.,	2) Surface phenomena, thermodynamics

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)	of surface phenomena, adsorption, Gibbs and Langmuir's isotherm adsorption
7. 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, the Gibbs-Helmholtz equations, the third law of thermodynamics (the Nernst heat theorem), the Planck postulate, chemical potential
8. Soustelle, M. An Introduction to Chemical Kinetics. Wiley Online Library, 2011. 448 p. URL://https://doi.org/10.1002/9781118604243 (Limited access)	1) Chemical kinetics and catalysis: the effect of temperature on the reaction rate, the Arrhenius equation, activation energy, methods of its determination
9. 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)	1) Phase equilibria: heterogeneous systems, the Gibbs phase rule, the Clausius-Clapeyron equation 2) Phase diagrams and properties of solutions. 3) Chemical equilibria: the law of mass action and the equilibrium constant, the isotherm equation, the isobaric and isochoric processes of a chemical reaction.
10. Степановских Е. И., Брусницына Л. А., Виноградова Т. В. Физическая химия для инженеров: учебник.: Изд-во Урал. ун-та, 2022. – 264 с. URL://https://elar.urfu.ru/bitstream/10995/113888/1/978%e2%80%915%e2%80%917996-3421-6_2022.pdf (Free access)	1) Phase equilibria: heterogeneous systems, the Gibbs phase rule, the Clausius-Clapeyron equation 2) Chemical equilibria: the law of mass action and the equilibrium constant, the isotherm equation, the isobaric and isochoric processes of a chemical reaction.
11. Черепанов В.А., Зуев А.Ю., Гаврилова Л.Я. и др. Физическая химия: Руководство для самостоятельной работы студентов: учеб.-метод. Пособие Изд-во Урал. ун-та, 2017. — 192 с. URL://https://elar.urfu.ru/bitstream/10995/52372/1/978-5-7996-2111-7_2017.pdf	1) The second law of thermodynamics (entropy, thermodynamic potentials, and characteristic functions). 2) The Gibbs fundamental equation, the Gibbs-Helmholtz equations, the third law of thermodynamics (the Nernst heat theorem), the Planck postulate, chemical

(Free access)	potential 3) Phase equilibria: heterogeneous systems, the Gibbs phase rule, the Clausius-Clapeyron equation 4) Phase diagrams and properties of solutions. 5) Thermodynamics of electrochemical systems: electrochemical potential and equilibrium conditions, the EMF of an electrochemical cell, electrode potential, the Nernst equation 6) The electrical conductivity of electrolyte solutions, ion mobility and transport numbers, the Debye–Hückel theory

Section 3. Organic chemistry

Sources	**Topic**
1. Clayden, Greeves, Warren. Organic Chemistry. Oxford University Press, 2000. Organic Chemistry, Clayden J., Greeves N., Warren S., 2012 (obuchalka.org) (Limited 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
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

Sources	Topic
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
4. Органическая химия. Учебник. Под ред. Н.А. Тюкавкиной. М.: Дрофа, 2003. 640 с. Тюкавкина Н.А. - Органическая химия.pdf (google.com) (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. Analytical chemistry

Sources	Topic
1. Christian G.D., Dasgupta K. (Sandy), Schug K.A. Analytical chemistry. Seventh edition // John Wiley & Sons, Inc. 2014. 826 p. URL:https://vulms.vu.edu.pk/Courses/CHE301/Downloads/Analytical%20Chemistry%207e%20by%20Gary%20D.%20Christian%20(1).pdf (Free access)	1) Theory of strong electrolytes. The total concentration and activity of ions in the solution. The ion activity coefficient and the ionic strength of the solution. 2) Application of the law of acting masses to acid-base equilibria. Buffer solutions. Calculation of pH solutions. 3) Qualitative analysis. Sensitivity of analytical reactions. The main analytical groups of cations and anions. 4) Titrimetric analysis. Methods of expression of concentrations used for calculations in titrimetric analysis. The molar mass of the equivalent. Calculation of the mass of the substance to be determined in the analyzed solution. Direct titration. Substitution titration. Reverse titration. 5) Types of titration. Acid-base titration. Redox titration. Sedimentary titration. Complexometric titration
2. Harris D.C. Quantitative Chemical Analysis // W. H. Freeman and Company, New York. 2010 http://orbitals.ir/wp-content/uploads/2017/01/Daniel-C.-Harris-Quantitative-Chemical-Analysis-8th-Edition-W.-H.-Freeman-2010-Www.Orbitals.ir_.pdf (Free access)	1) Application of the law of acting masses to acid-base equilibria. Buffer solutions. Calculation of pH solutions. 2) Qualitative analysis. Sensitivity of analytical reactions. The main analytical groups of cations and anions. 3) Titrimetric analysis. Methods of expression of concentrations used for calculations in titrimetric analysis. The molar mass of the equivalent. Calculation of the mass of the substance to be determined in the analyzed solution. Direct titration. Substitution titration. Reverse titration. 4) Types of titration. Acid-base titration. Redox titration. Sedimentary titration. Complexometric titration
3. Hibbert D. B. Introduction to electrochemistry. MacMillan Basingstoke, 1993. 350 p. https://g.eruditor.one/file/3316333/?ysclid=lm91p9ll37633832129 (Limited access)	1) Theory of strong electrolytes. The total concentration and activity of ions in the solution. The ion activity coefficient and the ionic strength of the solution.
4. Основы аналитической химии. В 2 т. Т.1 / [Т.А. Большова и др.]; под ред. Ю.А. Золотова. – 5-е изд. – М.: Издательский центр «Академия», 2012. – 384с. URL://https://portal.tpu.ru/SHARED/o/OAA/academic/Tab3/Основы%20аналит%20хими	1) Application of the law of acting masses to acid-base equilibria. Buffer solutions. Calculation of pH solutions. 2) Qualitative analysis. Sensitivity of analytical reactions. The main analytical groups of cations and anions.

и%201_Золотов.pdf (Free access)	3) Titrimetric analysis. Methods of expression of concentrations used for calculations in titrimetric analysis. The molar mass of the equivalent. Calculation of the mass of the substance to be determined in the analyzed solution. Direct titration. Substitution titration. Reverse titration. 4) Types of titrations. Acid-base titration. Redox titration. Sedimentary titration. Complexometric titration
5. Основы аналитической химии. В 2 т. Т.2 / [Н.В. Алов и др.]; под ред. Ю.А. Золотова. – 5-е изд. – М.: Издательский центр «Академия», 2012. – 416с. https://portal.tpu.ru/SHARED/o/OAA/academic/Tab2/Основы%20аналит%20химии%202_Золотов.pdf (Free access)	1) Types of titrations. Acid-base titration. Redox titration. Sedimentary titration. Complexometric titration

Section 5. Solid-state chemistry

Sources	**Topic**
1. Cowley John M. Diffraction physics. 1975 diffraction physics.pdf (fudan.edu.cn) (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_frontmat	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

ter.pdf (Limited access)	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)	1) 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 2) The electronic structure of solids: band theory, metals, semiconductors, and insulators, electron and hole conductivity
4. Анимица И. Е., Кочетова Н. А.. Квазихимическое описание процессов дефектообразования в оксидах: учеб. Пособие. Екатеринбург: Изд-во Урал. ун-та, 2019. — 102 с. elar.urfu.ru/bitstream/10995/68496/1/978-5-7996-2540-5_2019.pdf (Free access)	1) Point defects in crystals and the relationship between the concentration of impurities and intrinsic point defects, nonstoichiometry, and the environment of the sample
5. Горелик С.С., Дашевский М.Я. Материаловедение полупроводников и диэлектриков, Учебник для вузов, 2003. 480 с. Материаловедение полупроводников и диэлектриков, Учебник для вузов, Горелик С.С., Дашевский М.Я., 2003 (obuchalka.org) (Free access)	1) 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 2) The electronic structure of solids: band theory, metals, semiconductors, and insulators, electron and hole conductivity
6. Егоров-Тисменко Ю.К. Кристаллография и кристаллохимия. М.: КДУ, 2005. 589 с. https://www.geokniga.org/books/413 (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)
7. Китайгородский А.И. Рентгеноструктурный анализ. 1950. - 651 с. https://www.geokniga.org/books/2914 (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. https://www.geokniga.org/books/17658 (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. Уманский Я.С., Скаков Ю.А., Иванов А.Н., Расторгуев Л.Н. Кристаллография, рентгенография и электронная микроскопия. М.: Металлургия, 1982 https://www.geokniga.org/books/2911 (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. Физика металлов. Атомное строение металлов и сплавов. Учебник для вузов. М.: Атомиздат, 1978 URL: //lib-bkm.ru/load/99-1-0-2713?ysclid=lm915ajyp5428461191 (Free access)	1) 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 2) The electronic structure of solids: band theory, metals, semiconductors, and insulators, electron and hole conductivity
11. Шаскольская М.П. Кристаллография. Учеб. пособие для втузов. 2-е изд., перераб. и доп. - М.: Высшая шк. ,1984. - 376 с. Кристаллография - Кафедра кристаллографии СПбГУ (spbu.ru) (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)

Section 6. 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	1) Stress-strain (σ–ε) curve for solids (flow stress, yield stress, and ultimate tensile strength) 2) Fatigue of materials: fatigue limit, the characteristics of the cyclic stress-strain response, the fatigue curve

(Free access)	
2. Clyne, T.W., Hull, D. An Introduction to Composite Materials, Cambridge University Press, 2019. 360 p. URL:// https://www.academia.edu/73858336/INTRODUCTION_TO_COMPOSITES_MATERIALS_HULL (свободный доступ) (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://www.taylorfrancis.com/books/mono/10.1201/9780429265587/metallurgy-physicists-engineers-zainul-huda (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
4. Martin, R.M. Electronic Structure: Basic Theory and Practical Methods, Cambridge University Press, 2004. 650 p. URL:// /https://cds.cern.ch/record/821265/files/0521782856_TOC.pdf (Free access)	1) 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. Materials Kinetics Fundamentals | Wiley (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. Singh, S.B., Vakhrushev, A.V., Haghi, A.K. Materials Physics and Chemistry: Applied Mathematics and Chemo-Mechanical Analysis. CRC Press, 2021. 265 p.	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

URL://https://www.researchgate.net/publication/339385559_Materials_Physics_and_Chemistry (Limited access)	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. 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) 4) Stress-strain (σ–ε) curve for solids (flow stress, yield stress, and ultimate tensile strength) 5) The Fe-C diagram (transformations in steels; the structure and properties of steels)
8. 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) 3) Stress-strain (σ–ε) curve for solids (flow stress, yield stress, and ultimate tensile strength) 4) 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. Advanced chemistry (Coursera)

URL:// https://www.coursera.org/learn/advanced-chemistry
3. Chemistry (Coursera)
URL:// https://ru.coursera.org/learn/chemistry-1
4. Introduction to Chemistry: Reactions and Ratios (Coursera)
URL:// https://ru.coursera.org/learn/intro-chemistry
5. General Chemistry: Concept Development and Application (Coursera)
URL:// https://ru.coursera.org/learn/general-chemistry
6. Introduction to Chemistry: Structures and Solutions (Coursera)
URL:// https://ru.coursera.org/learn/basic-chemistry
7. Неорганическая химия. Часть 1. (Teach-in)
URL:// https://teach-in.ru/course/neorgchem1
8. Общая и неорганическая химия. Часть 1. Теоретические основы. (Urait)
URL:// https://urait.ru/author-course/obschaya-i-neorganicheskaya-himiya-v-2-ch-chast-1-teoreticheskie-osnovy-514851

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. Rasul Abdullaev, Leonid Braginsky, Arthur Pogosov: Basics of thermodynamics (Class Central) https://www.classcentral.com/course/thermo-dynamics-23740
3. Rafael Jaramillo, Jessica Sandland, John Harrold: Thermodynamics of Materials (Class Central)
URL:// https://www.classcentral.com/course/edx-thermodynamics-of-materials-21137
4. Alberto Salleo: Thermodynamics and Phase Equilibria (EDX)
URL:// https://www.edx.org/course/thermodynamics-and-phase-equilibria.
5. 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/
6. 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/
7. Physical Chemistry: Help & Review (Study.com)
URL:// https://study.com/academy/course/physical-chemistry-help-review.html
8. Free Online Course: Colloids and Surfaces from Swayam (Class Central)
URL:// https://www.classcentral.com/course/swayam-colloids-and-surfaces-19822
9. Физическая химия. Кинетика (Openedu)
URL:// https://openedu.ru/course/misis/CHKIN/
10. Физическая химия. Термодинамика (Openedu)
URL:// https://openedu.ru/course/misis/CHTHER/
11. Физическая химия дисперсных систем (Stepik)
URL:// https://stepik.org/course/Физическая-химия-дисперсных-систем-51631

Section 3. Organic chemistry

12. Органическая химия (teach-in.ru, МГУ)
https://teach-in.ru/course/organic-chemistry-p1?ysclid=lm9a1bxnnk25825917
13. Organic solar cells – Theory and Practice (Coursera)
URL:// https://ru.coursera.org/learn/solar-cell

14. Organic Chemistry (Youtube)
    URL:// New Organic Chemistry Playlist - YouTube
15. Crash Course Organic Chemistry (Youtube)
    URL:// Crash Course Organic Chemistry Preview - YouTube
16. Alkanes & Alkenes | Organic Chemistry | FuseSchool (Youtube)
    URL:// Alkanes & Alkenes | Organic Chemistry | FuseSchool - YouTube
17. Chemicals and Health (Coursera)
    URL:// https://ru.coursera.org/learn/chemicals-health

Section 4. Analytical chemistry

1. Analytical chemistry
URL:// https://extendedstudies.ucsd.edu/courses-and-programs/analytical-chemistry-1
2. The University of Tokyo: Basic Analytical Chemistry
URL:// https://www.edx.org/course/basic-analytical-chemistry
3. Analytical Chemistry and Measurement Science
URL:// https://www.manchester.ac.uk/study/online-blended-learning/courses/analytical-chemistry-and-measurement-science/
4. Free Online Analytical Chemistry Courses
URL:// https://alison.com/tag/analytical-chemistry

Section 5. 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 6. 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