

## Subject card

|                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                          |                                                    |                                     |                                                |            |     |
|---------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------|----------------------------------------------------|-------------------------------------|------------------------------------------------|------------|-----|
| Subject name and code                       | Physical chemistry, PG_00158587                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                          |                                                    |                                     |                                                |            |     |
| Field of study                              | Nuclear safety and radiological protection                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                          |                                                    |                                     |                                                |            |     |
| Date of commencement of studies             | October 2024                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                          | Academic year of realisation of subject            |                                     | 2025/2026                                      |            |     |
| Education level                             | Bachelor's studies                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                          | Subject group                                      |                                     | Obligatory subject group in the field of study |            |     |
| Mode of study                               | full-time studies                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                          | Mode of delivery                                   |                                     | at the university                              |            |     |
| Year of study                               | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                          | Language of instruction                            |                                     | Polish<br>not applicable                       |            |     |
| Semester of study                           | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                          | ECTS credits                                       |                                     | 7.0                                            |            |     |
| Learning profile                            | academic                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                          | Assessment form                                    |                                     | exam                                           |            |     |
| Conducting unit                             | Faculty of Chemistry -> Rector                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                          |                                                    |                                     |                                                |            |     |
| Name and surname of lecturer (lecturers)    | Subject supervisor                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                          | dr hab. Piotr Storoniak                            |                                     |                                                |            |     |
|                                             | Teachers                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                          | dr hab. Piotr Storoniak<br><br>Magdalena Mańkowska |                                     |                                                |            |     |
| Lesson types                                | Lesson type                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Lecture                                                  | Tutorial                                           | Laboratory                          | Project                                        | Seminar    | SUM |
|                                             | Number of study hours                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 30.0                                                     | 15.0                                               | 30.0                                | 0.0                                            | 0.0        | 75  |
|                                             | E-learning hours included: 0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                          |                                                    |                                     |                                                |            |     |
| Learning activity and number of study hours | Learning activity                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Participation in didactic classes included in study plan |                                                    | Participation in consultation hours |                                                | Self-study | SUM |
|                                             | Number of study hours                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 75                                                       |                                                    | 0.0                                 |                                                | 90.0       | 165 |
| Subject objectives                          | Acquainting students with the description of irreversible processes and the functioning of nature based on thermodynamics, with the phenomenological description of chemical changes over time based on chemical kinetics, with the description and applications of catalytic phenomena, and with the description and utilization of electrochemical processes. Acquiring the skills to understand and quantitatively describe physical transformations, chemical reactions, and to use physicochemical data in preparation for studying other subjects. |                                                          |                                                    |                                     |                                                |            |     |

| Learning outcomes | Course outcome                                                                                                                                                                                                                                                                                                                                                                                                                                       | Subject outcome                                                                                                                                                                                              | Method of verification                                                                                                                    |
|-------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
|                   | [BJORL3_W02] Understands the role of physical and chemical experimentation, mathematical theoretical models approximating reality, and computer simulations in scientific research methodology; is aware of technological, apparatus, and methodological limitations in scientific research                                                                                                                                                          | has knowledge of research techniques used in physicochemical research                                                                                                                                        | [SW4] test/exam - oral or written<br>[SW2] presentation/project/paper/report<br>[SW3] text preparation/written work                       |
|                   | [BJORL3_W05] has knowledge of the elementary components of matter and the types of fundamental interactions between them, the manifestations of these interactions in phenomena occurring at scales ranging from subatomic to subatomic, knows the time and energy scales associated with these phenomena; knows the basics of biology and ecology in understanding the biological and ecological aspects of nuclear safety and radiation protection | has general knowledge of the concepts and theories of physical chemistry, understands the molecular basis of physicochemical phenomena and processes occurring in nature                                     | [SW4] test/exam - oral or written<br>[SW2] presentation/project/paper/report<br>[SW3] text preparation/written work                       |
|                   | [BJORL3_U03] is able to use the formalism of physics and chemistry to describe phenomena in the microworld; is able to use the methodology of biology and ecology to an elementary extent when describing the effects of radiation on biological objects and in the environment                                                                                                                                                                      | is able to analyze problems and find their solutions based on laws and methods of physical chemistry                                                                                                         | [SU2] presentation/project/paper/report<br>[SU3] text preparation/written work<br>[SU4] test/exam - oral or written                       |
|                   | [BJORL3_W03] knows how to plan and perform a simple physical or chemical experiment and analyze the results obtained; knows the elements of the theory of measurement uncertainty as applied to experiments; knows the basic units of the SI system and its most important derived units; knows other systems of measurement units                                                                                                                   | identifies scientific and research equipment and explains the principles of its operation                                                                                                                    | [SW4] test/exam - oral or written<br>[SW2] presentation/project/paper/report<br>[SW3] text preparation/written work                       |
|                   | [BJORL3_U01] can formulate the basic laws of physics and chemistry using mathematical formalism                                                                                                                                                                                                                                                                                                                                                      | solves tasks using theories and formulas from the curriculum content of physical chemistry                                                                                                                   | [SU2] presentation/project/paper/report<br>[SU3] text preparation/written work<br>[SU4] test/exam - oral or written                       |
|                   | [BJORL3_U02] Has the ability to perform measurements of basic quantities used in physics and chemistry; can develop, describe and present the results of simple experiments and computer simulations; can perform quantitative analyses and formulate qualitative conclusions on this basis; can estimate measurement uncertainties                                                                                                                  | is able to plan and perform simple experimental tests or observations and analyze the results, draws conclusions from the conducted research and proves their correctness based on available literature data | [SU2] presentation/project/paper/report<br>[SU3] text preparation/written work<br>[SU8] observation of student's independent or team work |
|                   | [BJORL3_W01] has a general knowledge of the basic concepts and principles of nuclear physics and chemistry, understands their historical development and their importance not only for nuclear safety and radiation protection, but also for understanding the modern world; has a basic knowledge of biology and ecology                                                                                                                            | understands and is able to explain regularities, phenomena and processes using the language of mathematics, in particular is able to independently reproduce basic laws and theorems                         | [SW4] test/exam - oral or written<br>[SW2] presentation/project/paper/report<br>[SW3] text preparation/written work                       |

|                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                        |                               |
|---------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|
| Subject contents                | <p>Issues of the lecture:<br/> Basics of chemical thermodynamics of reversible processes, basic thermodynamic quantities, principles of thermodynamics. Phenomenological and molecular interpretation of energy and entropy. Thermodynamic criteria of equilibrium, equilibrium constant. Thermodynamics of the formation of ideal and real solutions. Physicochemical properties of gases, liquids and solids. Phase equilibria, phase diagrams, physicochemical description of distillation, rectification, crystallization and extraction processes. Chemical kinetics: elementary and complex processes, theory of absolute reaction rate. Homo- and heterogeneous catalysis: mechanisms, technological significance and in nature. Conductivity of electrolyte solutions. Dependence of conductivity on temperature, pressure and type of solvent. Theory of strong electrolytes. Relaxation and electrophoretic effect - Debye-Hückel-Onsager theory. Conductivity of electrolytes in solvents with low electric constant. Basics of electrochemistry. Spontaneous and forced electrochemical processes: cells, electrolysis. Corrosion phenomenon.</p> <p>Issues of auditorium exercises:<br/> Calculations of changes in internal energy, heat and work for physical processes and chemical reactions. Calculations of changes in entropy, free energy and free enthalpy of physical transformations and chemical reactions. Determination of the chemical equilibrium constant, calculation of free enthalpy based on the chemical equilibrium constant, van't Hoff isotherm. Phase equilibria, Gibbs phase rule. Identifying the order of reactions, deriving kinetic equations based on reaction mechanisms, determining the kinetics of complex reactions, deriving and using integrated forms of kinetic equations, calculations using the Arrhenius equation, active collision theory, transition state theory. Calculation of specific and equivalent conductivity, mobility and speed of movement of ions in solution, determination of ion transfer numbers using the Hittorf method and the moving boundary method, determining the hydrodynamic radius of ions. Using normal potentials to determine chemical equilibrium constants, calculations using the Nernst equation, determining the emf of a working cell and ion activity coefficients, calculating thermodynamic functions of reactions taking place in cells, calculating cell temperature coefficients.</p> <p>Laboratory exercises:<br/> Determination of the dissociation constant based on spectroscopic measurements; calculations based on the Lambert-Beer law; applications of spectroscopic measurements; principle of operation of a UV-VIS spectrophotometer; behavior of a molecule in an electric field; determination of the refractive index; principle of operation of a dielectrometer. Principle of calorimetric measurements (heat capacity, bomb calorimeter, limitations of the method); liquid-vapor equilibrium diagrams for infinitely miscible two-component systems (isotherms and isobars); leverage rule; fractional distillation of zeotropic and azeotropic systems; refractive index and its measurement. Basic types of physical adsorption isotherms (Langmuir, Freundlich, BET); specific surface area and its calculation; application of the adsorption phenomenon. Methods of measuring SEM and determining the activity coefficient; pH coefficient and its potentiometric measurement, pH meters, glass, calomel, quinhydrone, antimony electrodes, electrode characteristics. Determination of activation energy, influence of the catalyst on the reaction, precise control of the reaction temperature.</p> |                                                                                                                                                                                                                                                                                                                                                                                                                        |                               |
| Prerequisites and co-requisites | <p>The necessity to complete courses in: general chemistry, basics of advanced mathematics, and fundamentals of physics.<br/> Knowledge of general chemistry at the undergraduate level, familiarity with basic concepts and principles of mathematics and physics.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                        |                               |
| Assessment methods and criteria | Subject passing criteria                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Passing threshold                                                                                                                                                                                                                                                                                                                                                                                                      | Percentage of the final grade |
|                                 | written exam, closed and open questions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 51.0%                                                                                                                                                                                                                                                                                                                                                                                                                  | 50.0%                         |
|                                 | colloquium, closed and open questions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 51.0%                                                                                                                                                                                                                                                                                                                                                                                                                  | 25.0%                         |
|                                 | reports from laboratory exercises                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 51.0%                                                                                                                                                                                                                                                                                                                                                                                                                  | 25.0%                         |
| Recommended reading             | Basic literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | <p>P. Atkins, J. De Paula, J. Keeler, Atkins's Physical Chemistry, Oxford University Press, 2022.<br/> P. Atkins, Julio De Paula, Elements of Physical Chemistry, Oxford University Press, 2016.<br/> P. Atkins, Physical Chemistry: A Very Short Introduction, Oxford University Press, 2014.</p>                                                                                                                     |                               |
|                                 | Supplementary literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <p>P. Atkins, The Laws of Thermodynamics: A Very Short Introduction, Oxford University Press, USA, 2010.<br/> A. M. Steane, Thermodynamics: A Complete Undergraduate Course, Oxford University Press, 2016.<br/> R. M. Rosenberg, I. M. Klotz, Chemical Thermodynamics: Basic Concepts and Methods, Wiley-Interscience, 2008.<br/> C. H. Hamann, A. Hamnett, W. Vielstich, Electrochemistry, Wiley-VCH GmbH, 2007.</p> |                               |
|                                 | eResources addresses                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                        |                               |

|                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Example issues/<br>example questions/<br>tasks being completed | <ol style="list-style-type: none"> <li>1. Work, heat and changes in internal energy and enthalpy in the isothermal, isochoric, isobaric and adiabatic transformations of ideal gases.</li> <li>2. Derive the Clausius-Clapeyron law and show how the pressure of saturated vapor in equilibrium with the liquid should depend on temperature.</li> <li>3. Using the theory of active collisions, explain the origin of steric, pre-exponential and exponential factors.</li> <li>4. How does Lindemann's theory explain the second order of unimolecular reactions observed at low substrate pressures?</li> <li>5. Compare Hittorf's method with the moving boundary method. Describe the advantages and disadvantages of each method.</li> <li>6. Derive relationships between the electromotive force and its temperature coefficient and the thermodynamic functions of the reaction taking place in the cell.</li> </ol> |
| Work placement                                                 | Not applicable                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |

Document generated electronically. Does not require a seal or signature.