

Syllabus for the competitive examination for full-time and part-time doctoral studies

in "Processes and Equipment in Chemical and Biochemical Technology"

I. Modelling and optimisation of chemical and biochemical processes and systems

1. Theory of similarity. Basic concepts, similarity theorems. Transformation of differential equations by the similarity method. Basic principles of dimensional analysis.
2. Design of experiments (full and fractional factorial design). Statistical processing of experimental results (estimates and confidence intervals).
3. Statistical analysis of models. Basic concepts (random events and variables, mathematical expectation, variance).
4. Modelling of chemical engineering processes (model theories, criterial models, analogue models, regression models, etc.)
5. Optimisation of chemical and biochemical processes and systems. Basic concepts and definitions. Formulation of single-objective and multi-objective problems. Solution methods.

II. Processes and equipment in chemical technology

A. Hydrodynamic processes and separation of heterogeneous systems

6. Basic equations of fluid motion (continuity equation, Euler's differential equation, Navier-Stokes equation of motion). Similarity criteria.
7. Bernoulli's equation. Outflow of liquids from vessels.
8. Transport of fluids. Measurement of velocity and flow rate in pipelines. Frictional resistance in laminar and turbulent flow. Local resistances.
9. Separation of gaseous and liquid heterogeneous systems (separation methods), basic concepts and equipment design

B. Heat transfer processes

10. Basic equations and concepts. Fourier's law and thermal conductivity. Differential equations of heat conduction.
11. Differential equations of convective heat transfer. Determination of heat transfer coefficients in laminar and turbulent flow. Similarity criteria.
12. Heating and cooling. Methods and equipment design. Basic principles of heat exchanger calculation.
13. Condensation and evaporation. Methods and equipment design. Basic principles of the calculation of condensers and evaporation plants.
14. Intensification of heat transfer processes. Utilisation of waste heat and renewable sources of thermal energy.

C. Mass transfer processes

15. Fundamentals of mass transfer (driving force of mass transfer). Molecular diffusion (Fick's law). Convective diffusion, differential equation of convective diffusion. Similarity criteria.
16. Kinetics of mass transfer in the absence and presence of a chemical reaction. Mean driving force, mean and local mass transfer coefficient.
17. Absorption: equilibrium, kinetics, equipment design and calculations.
18. Distillation. Types of distillation processes and process flow schemes. Equilibrium, kinetics, equipment design and calculations.
19. Adsorption: equilibrium, kinetics, equipment design and calculations.

20. Extraction: equilibrium, kinetics, equipment design and calculations.
21. Ion exchange processes: equilibrium, kinetics, equipment design and calculations.

D. Chemical reactors

22. Fundamentals of chemical kinetics. Types of reactions. Rate of chemical reactions. Kinetic equations. Catalytic processes.
23. Main types of chemical reactors. Models of ideal reactors (perfect mixing and plug flow) and their hydrodynamics.
24. Mathematical models of chemical reactors accounting for mass and heat transfer: single catalyst pellet, fixed-bed catalytic reactor.

III. Biochemical processes and biotechnology

25. Enzymes – classification, specificity, nomenclature. Enzyme kinetics. Michaelis-Menten and Lineweaver-Burk equations. Inhibition of enzyme reactions.
26. Carbohydrates – mono-, di-, oligo- and polysaccharides – classification, structure, isomerism. Application as carbon sources in industrial biotechnology.
27. Carbohydrate catabolism. Anaerobic degradation – lactic acid and alcoholic fermentation. Aerobic degradation – Krebs cycle.
28. Microbiological methods – isolation of pure cultures, identification methods, cultivation and preservation of microorganisms. Sterility.
29. Kinetics of microbial processes. Monod equation. Kinetic models.
30. Types of fermentation processes – batch, fed-batch and continuous processes. Methods for recovery and purification of bioproducts from fermentation media.
31. Methods for optimisation of biotechnological processes – one-factor-at-a-time and multifactor optimisation. Statistical analysis – first- and second-order experimental design.
32. Development stages of biotechnological production – laboratory, pilot and industrial processes. Modelling and scale-up.

References:

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3. Sherwood, T. et al. Mass Transfer, Moscow, Khimiya, 1982 (in Russian).
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21. Sustainable Processes, Sustainable Systems, Sustainable Environment, edited by Prof. Dr. Natasha Vaklieva-Bancheva, BAS Publishing House "Prof. Marin Drinov", Sofia, 2020 (in Bulgarian).