UNIVERSITY of MISKOLC
Faculty of Materials and Chemical Engineering

Antal Kerpely Doctoral School of Materials Science & Technology

Sorption and Catalysis

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COURSE DESCRIPTION

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Sorption and Catalysis

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Lecturer

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Recommendation

The lecture is offered for all students of the Kerpely Doctral School, especially in the field of chemical metallurgy.

Language

English

Scope

The course aims to provide students with a comprehensive understanding of the physicochemical principles of sorption processes, the main sorption models, and their applications. Special emphasis is placed on gas adsorption measurements, data evaluation, the structure of porous materials, and the relevance of sorption in catalysis. Students will be able to interpret measurement results, select appropriate models, and correlate sorption data with structural and spectroscopic information.

Methodology

The course consists of theoretical lectures and practical data analysis exercises. The theoretical part introduces the thermodynamic and kinetic description of sorption and the most common isotherm models and their limitations. In the practical part, students evaluate real adsorption isotherms, calculate BET surface areas manually, and discuss measurement errors and interpretation strategies. For small groups, the course can be organized in a consultation format, adapted to the students' research topics.

Learning outcomes

After completing the course, students will be able to:

– explain the thermodynamic and kinetic principles of sorption processes;
– distinguish between different adsorption isotherm models and apply them to experimental data;
– calculate and interpret BET surface area and related parameters from gas adsorption measurements;
– describe the structural characteristics of porous materials and their influence on sorption;
– select appropriate characterization techniques for sorption and catalytic studies;
– evaluate and present experimental sorption data in a scientific context.

Topics

Introduction to sorption processes
– Fundamental concepts of physical and chemical sorption
– Thermodynamics of sorption: surface energy, enthalpy, entropy; spontaneity and temperature dependence of adsorption

Sorption models and isotherms
– Langmuir, BET, Freundlich, and Dubinin–Radushkevich models: applicability and limitations
– Near-linear isotherms (e.g. N_2 or CH_4 on non-polar surfaces at elevated temperatures, typically within limited pressure ranges)
– Description of multicomponent systems and competitive adsorption
– Hysteresis and pore structure effects: adsorption–desorption curve behavior
– Practical task: isotherm analysis, manual BET surface area calculation

Kinetic and diffusion processes
– Adsorption/desorption kinetics, diffusion limitations
– Dynamics of multicomponent systems
– Separation and storage examples (e.g. CO_2 capture, H_2 and CH_4 storage in porous materials)

Structure and types of porous materials
– Microporous, mesoporous, and macroporous systems
– Activated carbon, silicas, zeolites, metal–organic frameworks (MOFs), covalent organic frameworks (COFs), and other porous polymers
– Effect of material preparation and activation on sorption performance

Characterization methods
– Structural and morphological analysis: X-ray diffraction (XRD), electron microscopy (SEM, TEM), and thermogravimetric analysis (TGA)
– Surface area and pore size determination by gas adsorption
– Spectroscopic methods (IR, Raman): identification of surface components and functional groups
– Limitations and complementarity of methods

Relationship between sorption and catalysis
– The role of sorption in heterogeneous catalysis
– Surface, active sites, reaction steps, and kinetic aspects
– Catalyst efficiency, stability, and regeneration

Complex systems and data interpretation
– Combined methods (adsorption + spectroscopy + structural analysis)
– Case studies: adsorption and selectivity in multicomponent systems (e.g. CO_2/CH_4, N_2/CO_2 mixtures)
– Processing and presentation of student measurement results

References

1. Čejka, J.; Corma, A.; Zones, S. (eds.): Introduction to Zeolite Science and Practice. 3rd Edition, Elsevier, 2007.
2. Rouquerol, F.; Rouquerol, J.; Llewellyn, P.; Maurin, G.; Thommes, M.: Adsorption by Powders and Porous Solids: Principles, Methodology and Applications. Revised Edition, Academic Press (Elsevier), 2019.
3. Recent scientific papers in the fields of sorption, porous materials, and catalysis.

Exam

The course concludes with an oral examination and a short presentation or written report based on experimental results. Students present and interpret data from a selected sorption or catalytic system and propose further investigations.

Complex exam topics and sample questions

– Thermodynamic and kinetic description of sorption processes
– Sorption models and isotherms (Langmuir, BET, Freundlich)
– Structure and characterization of porous materials
– The role of sorption in heterogeneous catalysis
– Characterization and spectroscopic methods in sorption studies