The f-elements (C003768)

Valid as from the academic year 2017-2018

Course Specifications

Lecturers in academic year 2017-2018
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WE06 lecturer-in-charge

Course offerings and teaching methods in academic year 2017-2018
A (semester 1)
- seminar: coached exercises 7.5 h
- lecture 30.0 h
- practicum 15.0 h

Offered in the following programmes in 2017-2018
- Master of Science in Chemistry 6 A
- Exchange Programme in Chemistry (master's level) 6 A

Teaching languages
English

Keywords
f-elements, lanthanides, actinides, rare earths, coordination chemistry, spectroscopy, luminescence

Position of the course
This course is part of the Materials Chemistry profile in the UGent-VUB master in chemistry. The courses "Anorganische chemie: basisprincipes", "Spectroscopische analysemethoden" “Structuuranalyse”, and “Chemische binding” from the bachelor in chemistry education (UGent) are a direct preparation to this course. The goal of this course is to introduce students to the lanthanide and actinide series in the periodic table. These are the so-called “f-elements”, which are rarely touched upon in other chemistry courses. Practical lab sessions will illustrate the fundamental principles that are introduced during the theoretical classes.

Contents

THEORY:

Part 1: The 4f-elements: lanthanides
Chapter I: Introduction
I.1 The early days
I.2 Occurrence and abundance
I.3 Discovery and naming of the rare earth elements
I.4 Rare earth ores
I.5 Extracting and separating
I.5.1 Extraction
I.5.2 Separation
I.6 The position of the lanthanides in the Periodic Table

Chapter II: Principles and energetics
II.1 Electron configurations of the lanthanides
II.2 How f orbitals affect properties of the lanthanides
II.3 The lanthanide contraction
II.4 Patterns in ionization energies
II.5 Atomic and ionic radii
II.6 Patterns in redox potentials

Chapter III: Lanthanide coordination chemistry

(Approved)
III.1 Generalities
III.2 First and second order effects
III.3 Aqua ions
III.4 Other O-donors
  III.4.1 Monodentate ligands
  III.4.2 Polydentate ligands
III.5 N-donors
  III.5.1 Monodentate ligands
  III.5.2 Polydentate ligands
III.6 Mixed N-/O-donor ligands
III.7 Halides
III.8 S-donors
III.9 Extreme coordination numbers
III.10 Lanthanide organometallics

Chapter IV: The metallic state: alloys and uses of the rare earth metals

Chapter V: Geopolitics and economy of rare earths
  V.1 Rare earth supply versus demand
  V.2 Case study: recycling rare earths from fluorescent lighting

Chapter VI: Photophysical properties of the lanthanides
  VI.1 Energy levels and term symbols
  VI.2 Color of the trivalent lanthanide ions
  VI.3 Hypersensitive transitions
  VI.4 Lanthanide luminescence
    VI.4.1 Exciting the Ln\(^{3+}\) ions
    VI.4.2 Quenching
    VI.4.3 Dexter versus Förster energy transfer mechanisms
    VI.4.4 Luminescence decay times
    VI.4.5 Quantum yield
    VI.4.6 Using spectral fine structure for symmetry determination

Chapter VII: Rare earth β-diketone complexes
  VII.1 Background
  VII.2 β-diketones as ligands for rare earth ions
  VII.3 Synthetic pathways
  VII.4 Luminous lanthanide β-diketonate complexes
    VII.4.1 Photoluminescence
    VII.4.2 Electroluminescence

Part 2: The 5f-elements: actinides

Chapter VIII: Principles of radioactivity and modes of radioactive decay
  VIII.1 Nuclear stability
    VIII.1.1 Patterns of nuclear stability
    VIII.1.2 Neutron-to-proton ratio
    VIII.1.3 Mass defect
    VIII.1.4 Binding energy
  VIII.2 Radioactive decay
    VIII.2.1 Modes of decay
    VIII.2.2 Natural decay series

Chapter IX: Discovery, synthesis and naming of the actinide elements
  IX.1 Actinium, thorium, protactinium, uranium
  IX.2 The transuranium elements

Chapter X: Electronic properties of the actinides
  X.1 Orbitals and electron occupation
  X.2 Oxidation states and redox potentials
  X.3 Electronic spectra

Chapter XI: Actinide coordination chemistry
  XI.1 Specific issues
  XI.2 Coordination numbers
  XI.3 Actinyl ions
    XI.3.1 Bonding in the uranyl(VI) ion
    XI.3.2 Coordination geometries in uranyl(VI) complexes
  XI.4 Complexes of the other actinides
  XI.5 Actinide organometallics

Chapter XII: Synchrotron techniques to study actinide materials
  XII.1 X-ray Absorption Spectroscopy (XAS)
  XII.2 High-Energy X-ray Scattering (HEXS)
  XII.3 Examples
    XII.3.1 A lanthanide example
    XII.3.2 An actinide example

Chapter XIII: Actinides in nuclear energy generation
  XIII.1 Neutron induced fission
    XIII.1.1 Principles
    XIII.1.2 The pressurised light water reactor

(Approved)
XIII.1.3 The Oklo phenomenon
XIII.2 Uranium enrichment
XIII.3 Nuclear fuel reprocessing
XIII.4 Nuclear explosives
  XIII.4.1 Nuclear versus conventional explosives
  XIII.4.2 Fission bombs
  XIII.4.3 Fusion bombs
Chapter XIV: Transactinides and beyond...

PRACTICALS:
- Synthesis and (structural) characterization of some rare-earth coordination compounds
- Photophysical characterization: recording steady state and time-resolved luminescence data
- Interpretation of the luminescent behavior of a given lanthanide complex

Initial competences
The student should have successfully completed a bachelor in chemistry, and hence have sufficient knowledge of electrochemistry, basic inorganic chemistry and basic coordination chemistry.

Final competences
1. Having acquired knowledge on the electronic properties of the f-elements.
2. Having acquired knowledge on the coordination chemistry of the f-elements.
3. Having acquired knowledge on the photophysical properties of the lanthanides and to a lesser extent of the actinides; being able to interpret photophysical data with relation to the structure and properties of a given complex.
4. Understanding the relevance of most lanthanides and some actinides in every-day life.
5. Having acquired the practical skills to synthesize and characterize lanthanide coordination compounds.

Conditions for credit contract
Access to this course unit via a credit contract is determined after successful competences assessment.

Conditions for exam contract
This course unit cannot be taken via an exam contract.

Teaching methods
Lecture, practicum, seminar: coached exercises

Extra information on the teaching methods
The course will be taught "ex cathedra", and some of the theoretical aspects will be illustrated with coached exercises and practical lab exercises.

Learning materials and price
Course material: complete syllabus
Estimated price: 10.0 EUR
Keynote slides used during the theory classes will be made available via Minerva

References

Course content-related study coaching
Personal coaching on request

Evaluation methods
end-of-term evaluation

Examination methods in case of periodic evaluation during the first examination period
Written examination, oral examination, report

Examination methods in case of periodic evaluation during the second examination period
Written examination, oral examination

Examination methods in case of permanent evaluation
Skills test, job performance assessment, report

Possibilities of retake in case of permanent evaluation

(Approved)
Extra information on the examination methods

The permanent evaluation is based on the performance during the lab classes and the written report.
The exam consists of a combination of periodic evaluation (70%) and permanent evaluation (30%).

Calculation of the examination mark

Students must pass both the periodic evaluation and the permanent evaluation. In case a student does not pass for either the permanent evaluation or the periodic evaluation, the lowest mark is given.
Ramifications of the unfounded absence or non-participation in (part of) the permanent evaluation: the student does not receive a score and is indicated as 'absent' for the global mark.
In case the student passes both the permanent and periodic evaluation the end score is calculated as: 0.7*(score theory)+0.3*(score practicals).