UCLouvain

lphys1344b

2023

Subatomic, atomic and molecular physics - Atomic and molecular physics

3.00 credits	25.0 h + 30.0 h	Q2

Teacher(s)	Delaere Christophe ;Génévriez Matthieu ;Lauzin Clément ;
Language :	French
Place of the course	Louvain-la-Neuve
Prerequisites	It is recommended that students master the notions of quantum physics as developed in the course LPHYS1241. Having followed LPHYS1342 and having followed and passed LPHYS1231 are assets.
Main themes	This teaching unit consists of an introduction to subatomic, atomic and molecular physics. It discusses the experimental foundations of these three disciplines and introduces the main models associated with them. The relationship between experiment (and associated experimental methods) and the theoretical understanding of observed phenomena is emphasized. Different concepts are discussed, such as the life time and the interaction cross section, to account for the phenomena that take place within these bound systems (nucleus, atom or molecule). The description of these interactions by means of potentials (sometimes effective) of interaction or average potentials is introduced as a common denominator for all three sections of this teaching unit. In particular : • In subatomic physics, discoveries at the origin of a consistent description of the processes of strong and weak nuclear interactions are presented (discovery of the electron, nucleus and neutron, cosmic rays, muons, pions). The concepts of binding energy are then described together with a brief introduction to the liquid drop model, the layered model, and the Yukawa potential. The elementary particles that constitute these systems are then introduced very succinctly (without necessarily starting a mathematical description of the fundamental interactions between these elementary particles). • In atomic physics, after a brief review of the quantum description of the hydrogen atom, the Hartree-Fock model, the configuration interaction and the fine and hyperfine coupling are introduced more precisely. We introduce Einstein coefficients and multipolar radiative transitions. This description is extended to iso-electronic series and negative ions. • In molecular physics, we introduce the Born-Oppenheimer approximation and we give an introduction to the description of the different degrees of freedom, rotation and vibration, and their mutual interactions.
Learning outcomes	
Evaluation methods	The assessment of learning will be done by written exam. The learning outcomes of more advanced topics will eventually be subject to an oral evaluation. The written exam will include : - open and closed questions with short or long developments - problem-solving with quantified result.
Teaching methods	The learning activities consist of lectures, exercises, practical work, software manipulations and database consultations. The pedagogical material of the lectures are the blackboard and the slide show. The lectures are intended to introduce the fundamental concepts, to motivate them by showing examples and establishing results, to show their reciprocal links and their relations with the different parts associated with this teaching unit, and to establish links with the rest of the teaching units of the Bachelor in Physical Sciences. The practical work sessions aim to learn to use the ideas and formalism developed in subatomic, atomic and molecular physics in order to explain the results of experiments carried out in specific laboratory session or described in the framework of the lectures. These sessions will also allow students to choose and use calculation methods for their analysis, and to interpret the results obtained. The laboratories carried out during specific practical session or the descriptions of past experiences, aim to give an introduction to experimental methods in these three disciplines and to validate the theoretical concepts seen during the course or the establishment of theoretical concepts following the observation made in the laboratory.
Content	**I. Basic concepts** (hourly volume of 7h). 1. Brief history of nuclear and particle physics 2. Relativity and antiparticles 3. Space-time symmetries and conservation laws 4. Interactions and Feynman diagrams 5. Particle exchange: forces and potentials

	6. Observable quantities: cross-sections and decay rates **II. Atomic physics**. (hourly volume of 12h). 1. Explanation of the structure of atoms and ions based on a brief review of the results of quantum physics and spectroscopy. 2. Hydrogen-like systems, quantum defect, Rydberg states. 3. Multi-electron systems: Hartree-Fock method. 4. Central field and corrections, coupling schemes, isoelectronic series. 5. Radiative transitions, dipole approximation, multipolar transitions, selection rules, radiative cascades. 6. Stark effect and atomic polarizability, negative ions. **III. Molecular physics** (hourly volume of 12h). 1. The Born-Oppenheimer approximation. 2. Separation of coordinates. 3. Electronic states: molecular orbitals and atomic orbitals. 4. Vibrational states and rotational states. 5. Symmetries of diatomic molecules. 6. Correlation diagrams. 7. Radiative transitions, selection rules. **IV Subatomic physics phenomenology** (hourly volume of 14h). 1. Mass spectroscopy 2. Nuclear shapes and sizes 3. Semi-empirical mass formula: the liquid drop model 4. Nuclear instability 5. Decay chains 6. # decay phenomenology 7. Fission 8. # decays 9. Nuclear reactions 10. Leptons 11. Quarks 12. Hadrons
Inline resources	Various resources (slides and related documents) are put online via the MoodleUCL platform.
Bibliography	B. H. Bransden, C. J. Joachain (1990), "Physics of atoms and molecules", John Wiley and sons, ISBN-13: 978-0582356924. K. S. Krane, "Introductory Nuclear Physics", 3rd edition, ISBN: 978-0-471-80553-3. Brian R. Martin, Graham Shaw, "Nuclear and Particle Physics: An Introduction", 3rd Edition, ISBN: 978-1-119-34461-2. C. Foot (2005), 'Atomic Physics', Oxford University Press, ISBN: 9780198506966
Other infos	**Following the sanitary conditions, the modalities of the teaching AND the examination could be reassessed according to the situation and the rules in force.**
Faculty or entity in charge	PHYS

Programmes containing this learning unit (UE)				
Program title	Acronym	Credits	Prerequisite	Learning outcomes
Minor in Physics	MINPHYS	3		🔍