

Laser Photodetachment Threshold Spectroscopy on Radioactive Negative Ions

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2023.10.10 12:30

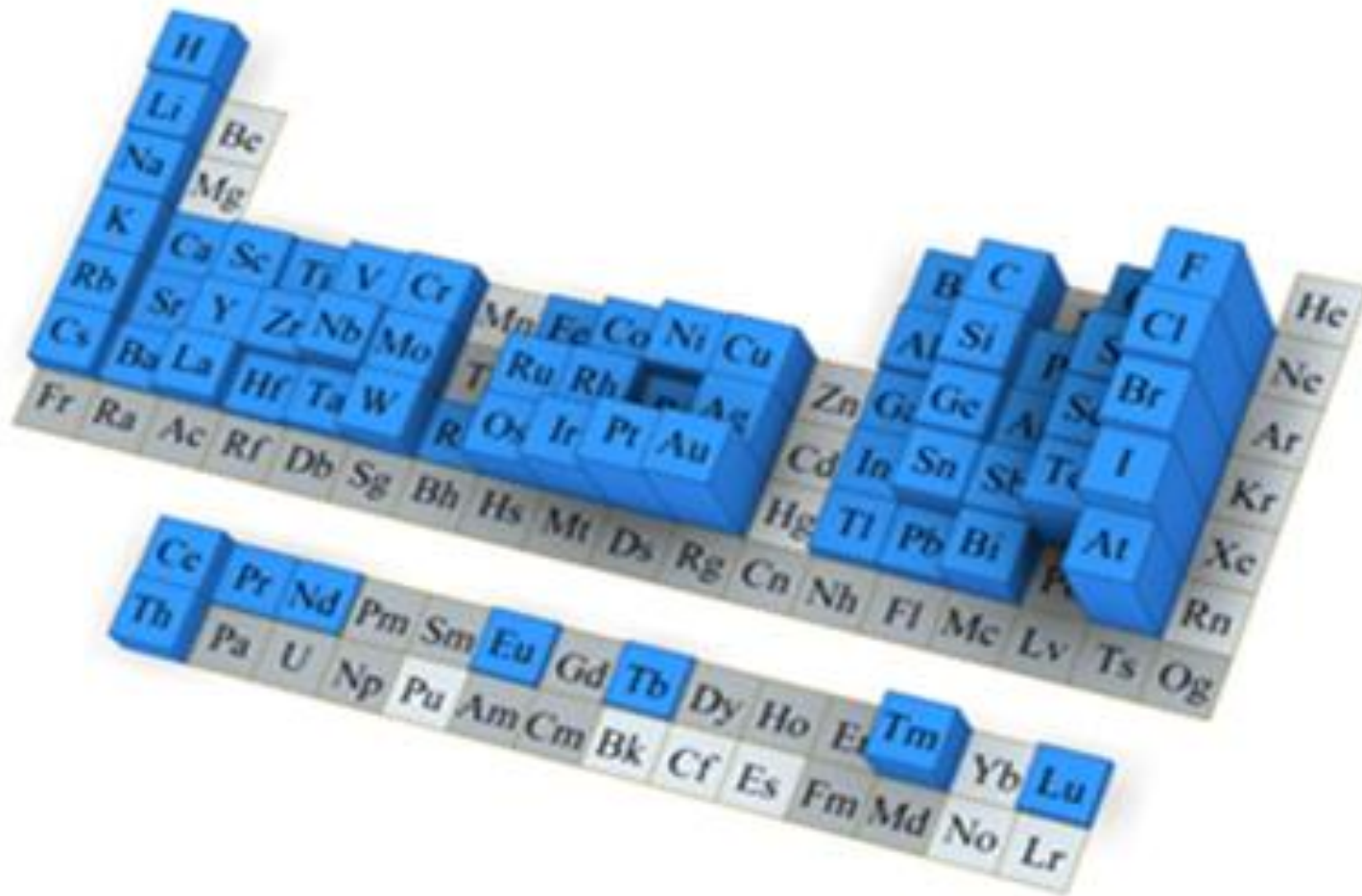
3rd CERN Baltic Conference 2023, October 9-11, Riga Technical University

Supported by ERDF project No. 1.1.1.5/19/A/003:
“Development of Quantum Optics and Photonics at University of Latvia”

ISOLDE we are doing spectroscopy of ions for nuclear physics research

- We are rookies, started only last year in this CERN Baltic league.
- Year2022 signed user's contract between CERN and ASI for 3 years with ~10% duty cycle and me as team leader
- Worked in CERN on development of MIRACLS and demonstration experiment, trapped Cl anions in June 2022.
- Reported results in 28th International Nuclear Physics Conference and few more, and manuscript for publication is in preparation
- Got idea for application for grant application at Latvian Council of Science for project based on experiments performed in CERN, Riga, Sweden.
- Finally, we received support for next 3 years, starting from year 2024

Negative ions, across the periodic table,



Blue- height indicates the measured EA.
Light gray- predicted to not exist,
Dark grey- does not have a clear prediction and here is room for experimental search

Suitable Chlorine isotopes for experiment and for comparison with theory.

- Mass34 31.99(3) min
- Mass35 stable
- Mass36 301300 y
- Mass37 stable
- Mass38 37.24(5) min
- Mass39 56.2(6) min
- Mass40 1.35(2) min

Isotope shift result for Chlorine anion.

Slide 1 16 / 34 90%

Isotope Shifts in the EA of $^{35,37}\text{Cl}$:

Parallel laser and ion beams
 \square ^{37}Cl
 \bullet ^{35}Cl

Most bound negative ion

$$\delta\nu_i^{A,A'} = K_i^{MS} \frac{M_A - M_{A'}}{(M_{A'} + m_e) M_A} + F_i(1 - \kappa) \delta \langle r^2 \rangle^{A,A'}$$

Measurable Normal mass shift Specific mass shift Volume shift

Kinematic calculation Atomic physics Nuclear physics

Electron correlation Charge radius

$0.22(14) \text{ GHz} = 0.74 \text{ GHz} - 0.51(14) \text{ GHz} + 0.014(14) \text{ GHz}$

Laser-bandwidth: 4.3 GHz

Theory: -0.535(51) GHz
 More precisely predicted in theory than experimentally measured

U. Berzinsh, et al. Phys. Rev. A 51, 231 (1995)
 Carette & Godefroid J. Phys. B: 46 (2013)

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Properties of atomic negative ions

- Binding of an extra electron to a neutral atom in a short-range potential is proportional to $\sim r^{-4}$ (for atoms and positive ions it is proportional to r^{-1}).
- Can usually only bind the fine or hyperfine structure states of the ground state term or in case of several terms of the energetic lowest lying ones
- Only for few negative ions few optical transitions are allowed.
- Therefore in most cases photodetachment threshold is measured.

MIRACLS- Multi Ion Reflection Apparatus for Collinear Laser Spectroscopy

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Laser Photodetachment Threshold Spectroscopy in an MR-ToF device

Chlorine ion source

ions

Paul trap with Helium buffer gas

ions

ion deflector for mass separation

MagneToF detector for detection of neutral atoms

CW Laser

neutrals

neutrals

ions trapped in MR-ToF device for up to several hundred milliseconds

sensitivity boost by reprobng same ion bunch

CW laser to increase precision

Chlorine ion source: PhD Thesis D. Leimbach (2021).
Remaining setup: modified MIRACLS low-energy setup, see e.g. F. Maier et al., *Hyperfine Interact.* 240, 54 (2019).
S. Sels et al., *Nucl. Instr. Meth. Phys. Res. B* 463, 310 (2020).

MIRACLS

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Thank you for attention!

And many thanks to my colleagues and key inspirers:

-Prof. Dag Hanstorp, University of Gothenburg, leader of negative ion activities at CERN

-Prof. Stephan Malbrunot CERN, ISOLDE, MIRACLS, project leader

-Dr. Erich Leistenschneider, CERN, ISOLDE, MIRACLS, principal investigator

-Prof. Rashid Ganeev, University of Latvia, ERA Chair holder

-Ass. prof. Jānis Alnis, University of Latvia , Deputy team leader in contract