Study of the neutron-rich tellurium isotopes by laser spectroscopy

- What kind of nuclear information from laser spectroscopy?
- Why measurements on the tellurium isotopes?
- Experimental methods and difficulties overcome
- Some experimental results
- Comparison with nuclear models
High resolution is required for tellurium isotopes, \( \lambda = 214 \text{ nm} \iff \nu \sim 10^6 \text{ GHz} \iff E \sim 6 \text{ eV} \)

\( \Delta \nu_{A,A+1} \sim 100 \text{ MHz} \)

thus we want to measure an effect < 10^{-7}

\( \rightarrow \) such resolution is obtained by laser spectroscopy

Nuclear data obtained from laser spectroscopy: \( \mu, Q_s, \delta<r^2> \)

\( \rightarrow \) by studying atomic transitions through long isotopic chains:
  - the hyperfine structure \( \rightarrow \mu, Q_s \)
  - the isotope shift \( \rightarrow \delta<r^2> \)

\( \rightarrow \) atomic properties used to obtain information on the nucleus
- kink at N = 82
  - observed in all isotope series with Z ≥ 54
  - in the proton-magic tin nuclei, still an open question
    - neutron-rich Te isotopes
  
  dynamic effects
  - observed in Cd, In and Sn (Z=48, 49, 50)
  - associated with a parabolic behaviour of δ<r^2>
  - not observed in isotope series with Z ≥ 54
    (quadrupole deformation)
    - neutron-deficient Te isotopes


Brigitte Roussière
ISOLDE Workshop February 6-8, 2006
COMPLIS at ISOLDE resonance ionization spectroscopy on laser-desorbed atoms
resolution $\sim 200$ MHz
$10^8$ atoms/frequency point

Neutron-rich Te isotopes: UC$_x$+hot plasma ion source
$4 \times 10^7$ atoms/mC for $^{136}$Te
$\Rightarrow$ $A = 127$ to $136$

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Ion source designed and built to produce stable beams of tellurium

- Ta cathode
- NiTe alloy
- Insulators made of boron nitride
- Kr inlet

Ion source designed and built to produce stable beams of tellurium
Ionization schemes

387 nm: doubling the frequency delivered by a pulse dye laser. No auto-ionizing level has been found. Efficiency very low: $5 \times 10^{-9}$.

355 nm: provided by the frequency tripling of a YAG laser. Efficiency: $5 \times 10^{-7}$. Isobars ionized directly by this intense UV laser beam.

Ionization scheme in three steps:
- Good efficiency
- Isobar ionization suppressed
Hyperfine structure of $^{125}$Te

$A = -0.995 (19)$ GHz

$A' = +0.951 (35)$ GHz

$\mu = -0.885051 (4) \mu_N$

$\Rightarrow \overline{H}_0$
Isotope shift

\[ \Delta v = \Delta v_{NMS} + \Delta v_{SMS} + \Delta v_{FS} \]

- when A changes \( \Rightarrow \) changes in the atom:
  - the reduced mass \( \Rightarrow \Delta v_{NMS} \)
  - the correlations between the e\(^-\) \( \Rightarrow \Delta v_{SMS} \)
  - the charge distribution in the nucleus
    \( \Rightarrow \Delta v_{FS} = F \times \lambda = F \times k \times \delta <r^2> \)

- F and \( \Delta v_{SMS} \) obtained from a King plot between our \( \Delta v \) values and the \( r_c \) values from muonic atom experiments [PRC39(1989)195]
  \( \Rightarrow F = 4.66 \pm 0.86 \, \text{GHz/fm}^2 \)
  \( \Rightarrow \Delta v_{SMS} = -1.89 \pm 0.33 \times \Delta v_{NMS} \)
Te isotopes

kink at N = 82
\[ \delta \langle r^2 \rangle : \text{comparison with static models} \]

Ref. \( HFB \) with D1S force, J. Libert, private communication

Ref. \( RMF \) with LN3 force, G. A. Lalazissis et al., ADNDT71(1999)1

\[ r_c(^{134}\text{Te})_{\text{exp}} = 4.752 \pm 0.004 \text{ fm} \]

\[ r_c(^{134}\text{Te})_{HFB} = 4.753 \text{ fm} \]

\[ r_c(^{134}\text{Te})_{RMF} = 4.761 \text{ fm} \]

- theoretical \( \delta \langle r^2 \rangle \) very similar except for \( ^{116}\text{Te} \) and \( ^{136}\text{Te} \)
- slope before \( N = 82 \) overestimated by both static models
- slope after \( N = 82 \) well reproduced by RMF
$r_c$: comparison with HFB calculations including dynamic effects

- $r_c$ slightly overestimated for $^{128-136}$Te close to $N = 82$
- perfect agreement from $^{126}$Te down to $^{120}$Te
- what happens in the neutron deficient isotopes?

Ref: J. Libert, private communication
COMPLIS collaboration for the tellurium study


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