John D’Auria, the relativistic chemistry of francium, and MeV-mass $\nu$’s

Otto Häusser, Peter Jackson, and John D’Auria started TRIumf’s Neutral Atom Trap “TRINAT”

- JDA’s interest: Chemistry of francium for its own sake
  S-states are sucked in by relativity
- We tried to trap $^{226}$Fr with TRINAT at TISOL
  Searched for MeV-mass $\nu$’s instead

M. Kalita and T. Hucko showed recent Fr physics results Monday
Organizers:
J. D’Auria,
D. Gil,
A. Yavin

T. Goldman HI 1993 tossing $\bar{p}$ at ceiling
D’Auria HI 81 275 1993 TISOL
Behr, Orozco, Sprouse, Gwinner et al.
HI 81 197 (1993) but I didn’t go (“$”)
I did read the conference summary:
O. Hausser HI 81 197 (1993)

• We trapped $^{79}$Rb at Stony Brook
• Otto hired me (4th choice) for TRINAT

‘1st TRINAT meeting’
JD’A, JB Apr’94 APS meeting:
JD’A: We wanna trap Fr and study it for its own sake
JB: I thought we were mostly doing $\beta$-$\nu$ correlations?
JD’A: Eh, that’s Otto (cough)

1993

Here Be Dragons

1994

Trapped in MOT

Radioactives trapped

Plans

Li Na K Ca Rb Sr Cs Fr Ne Ar Kr Xe

Dragons

Stony Brook

LBL

TRINAT  Fr @ TRINAT  $\nu$’s, $e^-$’s  Fr chemistry
TRINAT at TISOL: A good match for surface ion source for alkali production

- Developed stopper/neutralizer (flexible beamtime)
- Tried, then trapped $^{37}$K and measured $\langle r^2 \rangle$ (flexible beamtime)
- Tried to trap $^{226}$Fr
‘Simpler chemistry’: 1997 Neutralizer development

One day the trap was not working 😞, so we scrounged foils and tried out release:

Best release from BCC

Melconian et al 2005 NIMA
Miedema and Dorleijn Surf. Sci. 95 (1980) 477:
adsorption enthalpy related to bulk properties like $T_{melt}$ and work function

We tried lower-T foils →
lower-T foils

When Gorelov and I blew up the Lithium foil and went to lunch, JD’A cleaned box

Al didn’t work either

further backup from JD’A

J.B.’s only visit to TISOL front end:

One day, vacuum valves closed.
After 8 hrs: 5 Rem/hr

P.M. reconnaissance:
Polyethelyne (auxiliary) tubing cracked

J.B. capped the PolyFlo (50 sec), knocked over the cooling fan.
JD’A fixed the fan
1997 Attempt to trap $^{226}\text{Fr}$ at TISOL

Dube and Trinczek JOSA B
Iodine saturation spectr.
locked laser well

$^{226}\text{Fr}$ frequencies covered by existing AOM’s
$\text{ThO}$+egg white $\rightarrow$ ‘ThC’ was fine (chef JD’A) but
low yields for $^{226}$, $\beta$ decay geometry collected few photons

EEC: ‘If you’re going to do this, you have to do it right’

Francium trapped at ISAC $\ddagger$ 15 years later
MeV-mass $\nu$’s and cosmology

Trinczek... JD’A et al PRL 2003

Would produce slower nuclear recoils in $^{38mK} \rightarrow ^{38}Ar + \beta^+ + \nu$

Limits are in PDG

Gelmini PRL 2004 Such $\nu$’s don’t overclose the universe in cosmologies with low reheating temperature (MeV’s, enough to make BBN)
Low-energy $e^-$ ‘shakeoffs’ from $^{37}\text{K} \beta^+$ decay

JD’A+J. Vincent: Can TRINAT trap rhodium and measure $e^-$ energies? No, but:

Some higher-energy shakeoff $e^-$, but very few above threshold for double-strand DNA breaks, $\sim 25$ eV [Friedland Rad Res 150 172 (1998)]
Relativity binds S states deeper, changes $e^-$ g-factors

- Au is gold
- Hg is a liquid
- ekaRn $Z=118$ may have $e^-$ affinity $> 0$

Relativity has $\sim 10\%$ effect on Fr ionization potential

\[ \text{[Eliav Phys Ref A 50 (1994) 1121]} \]

\[ \text{g-factor of } S_{1/2} \text{ e}^- \text{ increases } 0.1\% \text{ with } Z \]

\[ \text{[Ekstrom 1986 Phys Scr 34; Dzuba 1985 Phys Scr Rel H-F]} \]
Cold chemistry: Photoassociation $\rightarrow$ Fr$_2$ molecular dimers

- Excite one atom to a P state, making a dipole interaction with the other.
- $C_3$ molecular potential $\rightarrow$ quantitative info on $\langle s|E_1|p \rangle$ to interpret atomic PNC interpretation.

Stony Brook (Orozco, Gomez, et al.) looked for Fr$_2$ and FrRb, did not see.

Aymar et al. JPB 39 2006 predict: greater Fr spin-orbit coupling $\rightarrow$ different dimer potential than Rb$_2$, Cs$_2$: similar rates, but fewer Fr$_2$ molecules near g.s.

Jones et al. RevModPhys 2006

Most efficient probe by far is photoionization, so TRINA T may be a better facility than FranciumTrappingFacility to do this.
John D’Auria, the relativistic chemistry of francium, and MeV-mass $\nu$’s

Many MOT’s for radioactives now

TRINAT testing phase needed regular beamtime from TISOL

JD’A and TRINAT:
J.D’A, Buchmann, Dombsky, Jackson, Sprenger, JB, 1997 NIMB on TISOL
J.B. PRL 1997 Trapping 37K
Melconian NIMB 2005 NIMA
Trinczek PRL 2003

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