Storing keV negative ions for hours: Lifetime measurements in new time domains

S. Mannervik[1], E. Bäckström[1], D. Hanstorp[2], O.M. Hole[1], M. Kaminska[1,3], R.F. Nascimento[1], M. Blom[1], M. Björkhage[1], A. Källberg[1], P. Löfgren[1], P. Reinhed[1], S. Rosèn[1], A. Simonsson[1], R. D. Thomas[1], H. T. Schmidt[1], and H. Cederquist[1]

[1] *Department of Physics, Stockholm University, AlbaNova University Center, SE-106 91 Stockholm, Sweden*

[2] *Department of Physics, University of Gothenburg, SE-412 96 Göteborg, Sweden*

[3] *Institute of Physics, Jan Kochanowski University, 25-369 Kielce, Poland*

Presenting Author: mannervik@fysik.su.se

We have measured the radiative lifetime of the $^2P^o_{1/2}$ level in S^- using the cryogenic electrostatic ion-storage ring DESIREE (Double ElectroStatic Ion Ring ExpEriment) [1–3]. The $^2P^o_{1/2}$ fine structure level is metastable and decays to the $^2P^o_{3/2}$ ground state through a slow magnetic dipole (M1) transition. We utilized a laser probing technique photo-detaching small fractions of the ions in a stored beam by a series of laser pulses. By using two different laser wavelengths we monitored the neutral yield due to detachment of ions in the metastable state only and due to detachment of ions in both the ground- and metastable states. The inverse of the longer (1/e)-lifetime when both states were detached was taken as a measure of the residual-gas density. We repeated these steps at slightly elevated ring temperatures of 15-17 K, which gave higher residual-gas densities than at 13 K. In Fig. (1) we show the decay rates for different residual-gas densities. The intercept with the vertical axis in Fig. (2) gives the inherent spontaneous lifetime of the $^2P^o_{1/2}$ level (τ=503±43 s) [3]. This is by far the longest lifetime ever measured for a negatively charged ion. The difference from the theoretical prediction 437 s is 1.3σ showing that the multi-configuration Dirac-Fock method applied in [4] may be appropriate to describe the features of excited fine-structure levels in atomic anions at this level of precision. The present results demonstrate the power of the new method and opens up for a broad survey of lifetimes of excited states in atomic ions in the time range from some tens of milliseconds to tens of minutes.

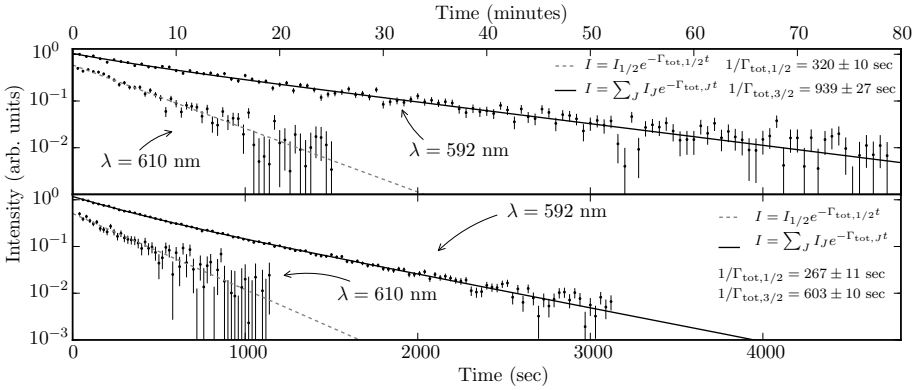

Figure 1: *Laser-probing measurements of only metastable (points for λ = 610 nm) and both metastable and ground-state-level populations (points for λ = 592 nm) as functions of time at 13 K (top) and at 15 K (bottom) (from ref. [3]).*

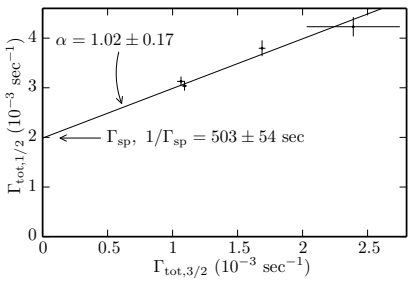

Figure 2: *Measured decay rate of the $^2P^o_{1/2}$ level (ordinate) plotted with measured decay rate of the $^2P^o_{3/2}$ level (abscissa) (from ref. [3]).*

References

[1] R. D. Thomas *et al.* Rev. Sci. Instrum. **82** 065112-1–18 (2011)
[2] H. T. Schmidt *et al.* Rev. Sci. Instrum. **84** 055115-1–6 (2013)
[3] E. Bäckström *et al.* Phys. Rev. Lett. **114** 143003-1–5 (2015) doi:10.1103/PhysRevLett.114.143003
[4] P. Andersson *et al.* Phys. Rev. A **73** 032705-1–8 (2006)