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The influence of the electronic environment on the decay rate of nuclei has been examined for a long time[1]. Internal conversion (IC) or electron capture are two decay processes which are very sensitive to the electron density distribution in the vicinity of the nucleus[2]. That explains why up to a recent time, the observed relative change of the half life remains at a magnitude of some few per cents when changing the physical or chemical environment or the electronic distribution in the outer shells of the radioactive atoms.

The first attempt to measure the effects of atomic charge state on nuclear lifetimes was made by Ulrickson et al in ^{197}Au ions. They found that the mean lifetime of the 77 keV level in ^{197}Au was not significantly affected by the removal of 10 electrons.

Since the emergence of large heavy ions accelerators, like Ganil in Caen or the FSR in Darmstadt, highly ionized ions can be accelerated leading to a wide choice in the nature, the energy and the charge state of the ions beams. Radioactive beam facilities under construction will enlarge the possibilities.

Recently two experiments have demonstrated that in highly ionized atoms the electronic configurations do have a drastic effect on the nuclear decay. In a first experiment the β decay was observed to bound electronic states of bare ^{163}Dy atoms[3]. In the neutral atoms the ^{163}Dy is stable. The change, infinitely large, of the decay rate is understood from energetic considerations which depends on the degree of ionization. The Q_β gains the binding energy of the electron appearing in the final atom[4]. Consequently, an energetically forbidden decay to a continuum state in a neutral atom becomes energetically possible in a bare ^{163}Dy. The second experiment, by Philipps

et al[4], concerns the measurement of conversion rates for the 14.4 keV excited state in ^{57}Fe ions with few electrons. A very significative change, 41 % increase, is observed in the decay rate of hydrogen like ^{57}Fe ions compared to the decay rate of Helium like ^{57}Fe ions. Contrasting with this strong variation the decay rate remains almost constant within 5 %, for charge states ranging between q = 24 and q = 0.

In the present experiment we report on a large increase of the lifetime of the first excited state in ^{125}Te due to a strong variation of the internal conversion coefficient with the charge state, α_{Ic}^{q}.The variation is associated with both energetic considerations as in the bound β decay and a selective population of the electronic state in the Te ions.

In ^{125}Te the first $3/2^+$ excited level is located at an energy of 35.46 keV above the ground state. This level decays by an almost pure M1 transition (99.96 %). In a neutral ^{125}Te the main decay channel of this level is the IC of the M1 transition on a K-shell electron. The K-shell internal conversion coefficient in the neutral atom is $\alpha_K^o = 12.01$. The remaining decay channels are the internal conversion on L_1, $L_{2,3}$ shells with respective IC coefficient values in a neutral atom $\alpha_{L1}^o = 1.46$, $\alpha_{L2,3}^o = 0.17$, and the emission of a magnetic dipole photon. The lifetime of the 35.46 keV transition in the neutral atom has been measured $T^o = 1.5$ ns[5]. It is related to the total decay width Γ_T^o by the uncertainty principle :

$$T^o = \hbar / \Gamma_T^o \qquad (1)$$

Where Γ_T^o can be expressed in term of the partial radiative width Γ_γ^o and the IC coefficient values α^o :

$$\Gamma_T^o = \Gamma_\gamma^o \left(1 + \alpha_K^o + \alpha_L^o + \alpha_M^o + \ldots\right) \qquad (2)$$

In the neutral atom the binding energy of the electron is well established. For example the binding energy of the K-shell for a neutral Te is E_K^o = 31.8 keV (see reference). The electronic wave functions and therefore the binding energy, of the inner electron are affected by the removal of the outer electrons, through the screening and the exchange potentials. For increasing Te charge states, ranging between a neutral configuration to a hydrogen like configuration, the binding energy of the K-shell electron varies between $E_K^o = 31.8$ to $E_K^{51+} = 38.1$ keV. For one particular charge state, called here-after the critical charge state q_c, the binding energy of one K-shell electron E_K^{qc} becomes larger than the available energy in the nuclear transition. In such

configuration, the IC on a K-shell electron becomes energetically forbidden in spite of the presence of the two K-shell electrons. Consequently the mean lifetime is suddenly increased by a factor corresponding to the suppression of the IC coefficient α_K^o in equation (2). Using a simplified model[12] to calculate the binding energy of the K-shell electron we obtain for $q_c = 46$ a value E_K^{46} exceeding the transition energy by 0.2 keV.

EXPERIMENTAL

The experimental technique follows the procedure exposed by Phillips et al[4,11]. A beam of ^{125}Te has been accelerated at Ganil to an energy of 27 MeV/amu. The charge state of the beam was $q = 38^+$. The beam was impinging upon a 1 mg/cm^2 target of ^{232}Th mounted at a distance d = 11 cm before the entrance of the magnetic spectrometer SPEG[6]. At the exit of the target the ^{125}Te has a Gaussian charge state distribution centred on $q = 47^+$ with a FWHM $\Delta q = 2$ in excellent agreement with theoretical calculations based on cross sections for electron capture and ionization by heavy ions in thin solid targets.

Furthermore, after passing through the ^{232}Th target some excited nuclear levels connected to the ground state by large electric quadrupole matrix elements are populated by a nuclear Coulomb excitation mechanism. These levels have very short lifetimes (<10^{-9}ns) and partially decay to the first excited level at 35.46 keV. The branching ratios are known. From the works of Sergolle et al[8] and Barrette et al[9] who measured the $B(E_2)$ values, the feeding probability of the first level in ^{125}Te can be determined.

At the exit of the Th target we have selected the ^{125}Te ions which have been scattered at an angle of (42 ± 4) mrad with respect to the incident beam direction. The angular direction was defined by a 1 mm wide rectangular aperture in front of the target and a movable 0.1 mm wide slit mounted in the magnetic field entrance of the dispersive spectrometer SPEG. The grazing angle in the system ^{125}Te + ^{232}Th at 27 MeV/amu is equal to 105 mrad in the laboratory system.

Immediately after the slit, different species of ^{125}Te ions are coexisting before entering the magnetic field in SPEG :

a) ^{125}Te ions in the nuclear ground state and in different atomic charge states ranging between q = 50 and q = 43.

They follow trajectories which are defined by the magnetic rigidity, the angle of incidence in the spectrometer, the energy resolution of the beam and the charge state[6]. The X and Y positions of the ^{125}Te at the exit of the magnetic spectrometer are detected event by event in two identical systems separated by a distance of 1.935 m. Each system consists of a parallel plate giving a fast trigger signal and a drift chamber

to analyze the position. At the end the ions are stopped in an ionization chamber which gives the value of the energy of each ion with an energy resolution of 2 %.

b) ^{125}Te ions which have been excited in the first nuclear state by Coulomb interaction with a charge state $q < q_c$.

Before entering the magnetic field, most of the excited nuclear states have enough time to decay to the nuclear ground state by internal conversion because the lifetime of the first excited nuclear state in the neutral atom is of the order of the time of flight between the target and the magnetic field entrance. During the process, a conversion electron has been emitted in the continuum. These ^{125}Te ions enter into the spectrometer with a charge state (q + 1). They cannot be distinguished from the Te ions seen in (a) which have been formed directly in a charge state (q + 1).

c) ^{125}Te ions which are nuclear excited with a charge state $q \geq q_c$

Their decay length is expected to be larger than the distance d, due to the half-life T^{q_c} increasing by a large factor. The greatest part of such ions enters into the magnetic field with a charge state q and begins to follow the corresponding trajectory of the ^{125}Te (q). At some position inside of the spectrometer SPEG the nuclear state decays. One part of the decay arises by photon emission and the other part arises by internal conversion on the remaining L shell electrons, inducing a change in the charge state. The ^{125}Te (q) ions become ^{125}Te (q + 1) ions which follow a different trajectory in the magnetic field, and hit the drift chambers at a position between the ^{125}Te(q) and ^{125}Te(q + 1) peaks.

Fig. (1) presents the distribution of the ^{125}Te ions in the second drift chamber. A gate has been set on the elastic part of the energy distribution of the ions scattered at 42 mrd. The lifetime variation effect is clearly seen. The intervals between peaks 45-46 and 46-47 are free of counts, but a few background events. For the corresponding charges 44 and 45, the half life of the $3/2^+$ level is to small (~ 1.5 ns) to produce trajectories crossing the detection plane far from the peak positions.

On the contrary, beyond the 47^+ charge state counts are found between the peaks, with a nearly exponential distribution, due to a strongly enhanced lifetime of the level. Since the modification of the charge during the flight produces events located on the high energy side of the peaks, such events cannot be confused with energy loss background events.

The total intensity and the distribution of the counts are used to deduce the lifetimes associated to the different charge states. A simulation program, based on the code Turtle[10], has been developed to achieve a quantitative interpretation of the data. The simulation results corresponding to our experimental situation are shown in Fig.(1) and Fig.(2). The feeding probability of the first state has been taken equal to $P_c = 1.3\ 10^{-3}$. In these figures we have assumed a constant half-life values equal respectively to 1.5 ns and 6 ns for the first excited level of ^{125}Te. The simulations are

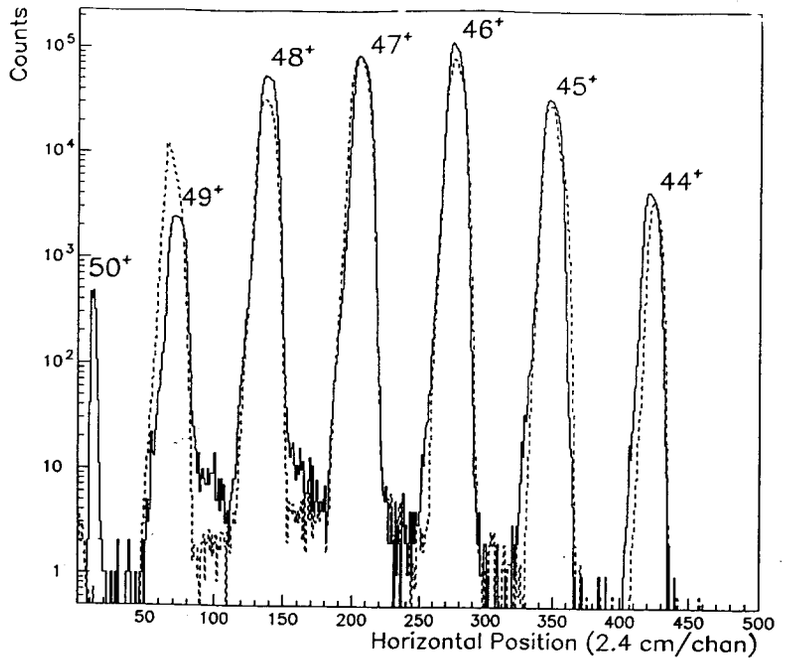

Fig. 1 : Experimental distribution of the $^{125}Te^{(q)}$ ions location in the drift chamber showing the change of the trajectories of the $q > 47$ ions inside of SPEG according to the different nuclear lifetimes of the first excited state. The computer simulation is shown (dashed line) for a constant value $T_{1/2} = 1.5$ ns in the neutral atom (see text)

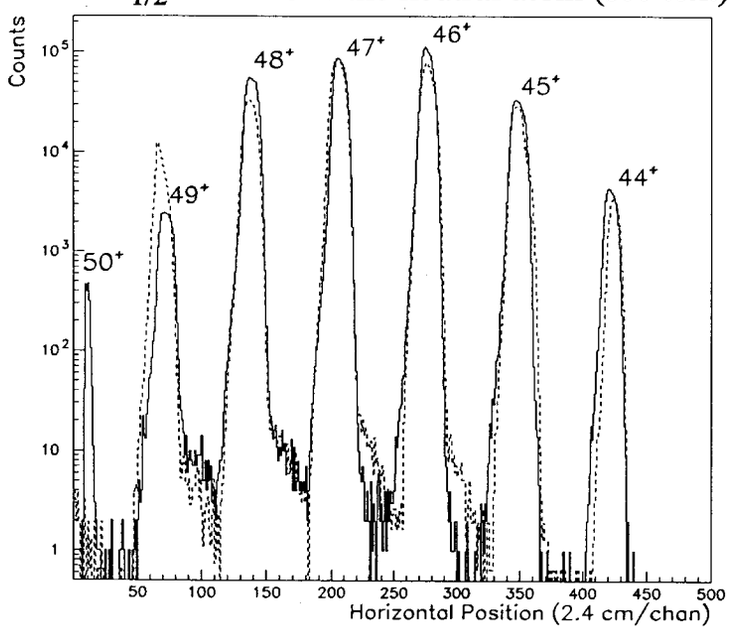

Fig. 2 : Comparison of the experimental distribution with the computer simulation result of the decay of the ^{125}Te ions inside the magnetic spectrometer SPEG assuming a constant value $T_{1/2} = 6$ ns for the lifetime of the first excited state

normalized to the experimental 47^+ charge state. The distribution of the intensities in the different charges follows the theoretical one.

It is seen that the simulation reproduces very well the major features of the experimental data, evidencing the large enhancement of the nuclear period for a critical charge state q = 47.

The difference in the lifetimes for the $T_{1/2}^{47+}$ and $T_{1/2}^{48+}$ are due to the population of $^3P_{0,2}$ metastable states in the Be-like ^{125}Te ions. In the B-like configuration we find a value $T_{1/2}^{47} = (6 \pm 2)$ns. This lifetime correspond to the conversion of the 35.46 keV transition in the $2s^22p^1$ electronic configuration. Taking as a reference the value of the ICC $\alpha_{L_1}^{o} = 1.4$ in a neutral atom, the expected value of $T_{1/2}$ would have been equal to 9 ns.

CONCLUSION

We have shown for the first time a very strong energy threshold effect in the internal conversion process.

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