Lifetime measurements in ^{36}Ar and ^{36}Cl using the recoil distance method.

1973 J. Phys. A: Math. Nucl. Gen. 6 L37

(http://iopscience.iop.org/0301-0015/6/4/003)

J. Phys. A: Math., Nucl. Gen., Vol. 6, April 1973. Printed in Great Britain. © 1973

LETTER TO THE EDITOR

Lifetime measurements in ^{36}Ar and ^{36}Cl using the recoil distance method†

P J Nolan, P A Butler, P E Carr‡, L L Gadeken, A N James, J F Sharpey-Schafer and D A Viggars

Oliver Lodge Laboratory, University of Liverpool, PO Box 147, Liverpool L69 3BX, UK

MS received 15 February 1973

Abstract. The recoil distance method has been used to measure the mean lifetimes of the 788 keV, 1164 keV, 2519 keV and 2810 keV levels in ^{36}Cl and of the 4178 keV and 5171 keV levels in ^{36}Ar. The measured lifetimes are 30 ± 1 ps, $7{\cdot}1 \pm 0{\cdot}5$ ps, $2{\cdot}36 \pm 0{\cdot}16$ ns, $9{\cdot}0 \pm 0{\cdot}6$ ps, less than 8 ps and 127 ± 5 ps respectively. The data support a correspondence between the 2519 keV and 2810 keV levels of ^{36}Cl with 5^- and 4^- states given by the shell model calculations of Erné.

As part of a study of ^{36}Ar and ^{36}Cl the mean lifetimes of a number of levels have been measured using the recoil distance method. The levels were populated using the ^{33}S(α, n)^{36}Ar ($Q = -2{\cdot}00$ MeV) and ^{33}S(α, p)^{36}Cl ($Q = -1{\cdot}93$ MeV) reactions at two bombarding energies. The apparatus used is similar to that described by Alexander and Bell (1970), the distances being found by the capacitance measuring technique. The target consisted of 25 μg cm^{-2} CdS (sulphur enriched to 90% ^{33}S) evaporated onto a stretched gold foil of 2 mg cm^{-2} thickness. The stopper was made of 250 μm tantalum.

The first experiment was carried out at an α particle bombarding energy of 7·1 MeV. An escape suppressed spectrometer (Sharpey-Schafer *et al* 1971) was used to detect γ rays at 0°, relative to the beam direction, and at 15 different target–stopper distances. The range being 29 μm to 8 mm. At this beam energy the 788 keV and 1164 keV levels in ^{36}Cl were populated. The peaks in the γ ray spectra were fitted, assuming gaussian shapes, using a nonlinear least-squares technique (Helmer *et al* 1967) to find the area of the 'stopped' peak, I_0, and the area of the Döppler shifted peak, I_s. The ratio $I_0/(I_s+I_0)$ has been plotted against distance for the 788 keV and 1164 keV γ rays in figures 1(*a*) and 1(*b*) respectively. The decay curves were fitted with an exponential plus a constant background. In the case of the 1164 keV γ ray the curve was constrained to pass through the point $I_0/(I_s+I_0) = 1$ at $d = 0$. The distance scale had previously been determined to be correct to within 2 μm from the fit for the 788 keV γ ray. Corrections were applied for velocity spread, efficiency of the detector and detector solid angle using the methods outlined by Jones *et al* (1969). The mean recoil velocity was determined from the difference between the centroids of the 'stopped' and 'shifted' peaks. It was found to be $(0{\cdot}60 \pm 0{\cdot}01)$% of the velocity of light for both levels in this experiment. The measured mean lifetimes are given in table 1.

† Work supported by UK Science Research Council

‡ Present address: Ferranti Ltd, Western Road, Bracknell, Berkshire RG12 1RA, UK.

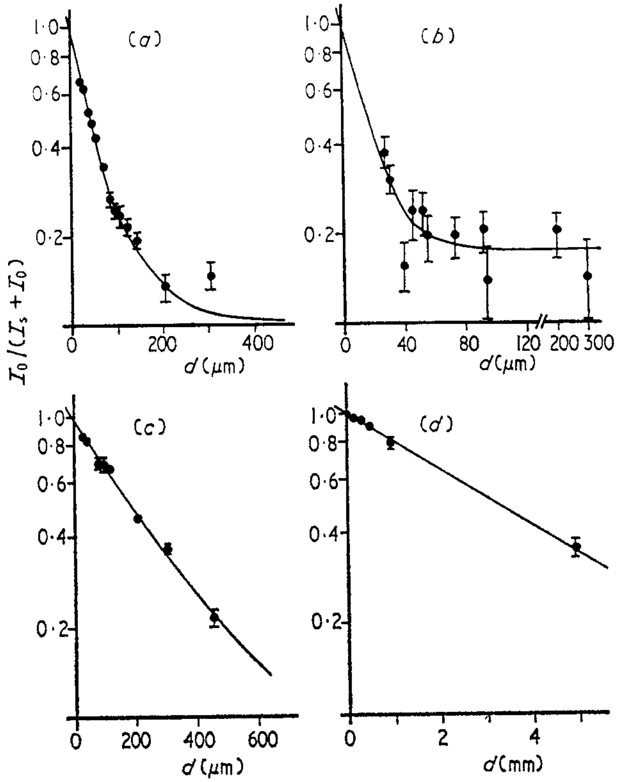

Figure 1. Plots of $I_0/(I_s+I_0)$ against distance for: (*a*) 788 keV level in ^{36}Cl, E_γ = 778 keV, τ = 30±1 ps; (*b*) 1164 keV level in ^{36}Cl, E_γ = 1164 keV, τ = 7·0±0·5 ps; (*c*) 5171 keV level in ^{36}Ar, E_γ = 993 keV, τ = 127±5 ps; (*d*) 2519 keV level in ^{36}Cl, E_γ = 1731 keV, τ = 2·36±0·16 ns. The 8 mm point for (*a*), (*b*) and the 13·5 mm point for (*c*), (*d*) are not shown in the diagram.

Table 1. Mean lifetimes in ^{36}Ar and ^{36}Cl

Nucleus	E_x (keV)	E_γ (keV)	τ (ps)
^{36}Ar	4178	2209	< 8
^{36}Ar	5171	993	127±5
^{36}Cl	788	788	30±1
^{36}Cl	1164	1164	7·1±0·5
^{36}Cl	2519	1731	2·36±0·16 ns
^{36}Cl	2810	2022	9·0±0·6

The second bombarding energy used was 8·7 MeV, resulting in a mean recoil velocity of v/c = (0·68±0·01)%. Measurements were taken at 11 different target–stopper distances, ranging from 25 μm to 13·5 mm, on the 4178 keV and 5171 keV levels in ^{36}Ar and the 2519 keV and 2810 keV levels in ^{36}Cl. The results were analysed as described above and the mean lifetimes are given in table 1. The decay curves for the 993 keV γ ray from the 5171 keV level and the 1731 keV γ ray from the 2519 keV level are shown in figures 1(*c*) and 1(*d*) respectively.

At the beam energy chosen the 4178 keV (3^-) level in ^{36}Ar was fed by the 993 keV γ ray from the 5171 keV (5^-) level. The measured lifetime of less than 8 ps includes a correction to allow for this. The deduced E3 strength for the $3^- \rightarrow 0^+$ ground decay is greater than 7 Wu (Weisskopf single particle units). This value is compared with the E3 decay of the first 3^- levels of other even–even self-conjugate nuclei in the s–d shell in figure 2. The upper limit on the transition strength for the 4178 keV γ ray in ^{36}Ar

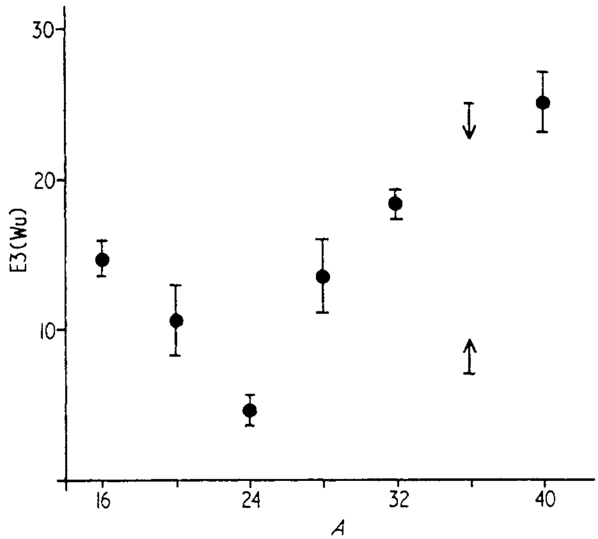

Figure 2. The E3 strengths of the ground state decay of the first 3^- level in even–even self-conjugate nuclei in the s–d shell. For ^{36}Ar our measurement is shown as a lower limit, the upper limit coming from Thibaud *et al* (1970). All other values are taken from the literature, where more than one value has been reported the mean has been taken.

comes from the lifetime of greater than 2 ps measured using the Döppler shift attenuation method by Thibaud *et al* (1970). The lifetime of the 5171 keV level is 127 ± 5 ps. The E2 transition strength for the decay of this 5^- level to the 4178 keV (3^-) level is $(0{\cdot}75 \pm 0{\cdot}05)$Wu.

The 2519 keV and 2810 keV levels in ^{36}Cl have been shown to have $l = 3$ character by Decowski (1971). Shell model calculations by Erné (1966), using an inert ^{32}S

Table 2. Transition strengths in ^{36}Cl assuming pure decays

E_x (keV)	E_γ (keV)	Decay	Relative intensity (%)	E1 (Wu)	M2 (Wu)	E3 (Wu)
2519	2519	$J^- \rightarrow 2^+$	5	$(1{\cdot}2 \pm 0{\cdot}1) \times 10^{-9}$	$(8{\cdot}6 \pm 0{\cdot}6) \times 10^{-4}$	$0{\cdot}75 \pm 0{\cdot}05$
	1731	$J^- \rightarrow 3^+$	95	$(7{\cdot}0 \pm 0{\cdot}5) \times 10^{-8}$	$1{\cdot}1 \pm 0{\cdot}1$	198 ± 14
2810	2022	$J^- \rightarrow 3^+$	80	$(9{\cdot}6 \pm 0{\cdot}6) \times 10^{-6}$	$10{\cdot}8 \pm 0{\cdot}7$	$(1{\cdot}5 \pm 0{\cdot}1) \times 10^4$
				M1	E2	M3
	860	$J^- \rightarrow 2^-$	20	$(1{\cdot}1 \pm 0{\cdot}1) \times 10^{-3}$	$5{\cdot}5 \pm 0{\cdot}3$	$(5{\cdot}2 \pm 0{\cdot}3) \times 10^7$

core and allowing one particle in the $f_{7/2}$ shell, predict 5^- and 4^- levels in the $(d_{3/2})^3 f_{7/2}$ configuration at 2·62 MeV and 2·92 MeV respectively. His predictions of 2·17 MeV and 2·50 MeV for the 2^- and 3^- levels of this configuration are in good agreement with the experimental values of 1·95 MeV and 2·46 MeV. The 2519 keV level decays to the 2^+ ground state and the 3^+ 788 keV level, while the 2810 keV level decays to the 788 keV level and the 2^- 1950 keV level. The transition strengths for these decays are given in table 2. They are consistent with J^π assignments of 5^- and 4^- respectively, although other assignments cannot be ruled out.

We thank Professor L L Green for his continuing interest, and Mr J B Reynolds for making the targets. Two of us (PJN and DAV) acknowledge the receipt of SRC postgraduate studentships during the period of this work.

References

Alexander T K and Bell A 1970 *Nucl. Instrum. Meth.* **81** 22–6
Decowski P 1971 *Nucl. Phys.* A **169** 513–20
Erné F C 1966 *Nucl. Phys.* A **84** 91–105
Helmer R G *et al* 1967 *Nucl. Instrum. Meth.* **57** 46–57
Jones K W *et al* 1969 *Phys. Rev.* **178** 1773–82
Sharpey-Schafer J F *et al* 1971 *Nucl. Phys.* A **167** 602–24
Thibaud J P *et al* 1970 *J. Phys., Paris* **31** 131–4