# ON THE DECAY OF $^{110}Sb$, $^{111}Sb$, $^{112}Sb$, $^{113}Sb$ AND $^{114}Sb$†

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The nuclear structure of the Sb and Sn isotopes has been the subject of numerous experimental and theoretical investigations. It is of particular interest to extend these studies to the region of the neutron deficient isotopes, primarily to see how well these isotopes remain "superconducting" as one approaches the doubly magic structure $^{100}Sn$.

Two previously unknown light antimony isotopes, $^{110}Sb$ and $^{111}Sb$, have been produced through the (p,3n) and (p,2n) reactions on $^{112}Sn$, respectively. The gamma spectra following their beta decay have been studied, together with those of $^{112}Sb$, $^{113}Sb$ and $^{114}Sb$, produced by (p,xn) reactions on $^{112}Sn$ and/or $^{114}Sn$. Enriched metallic $^{112}Sn$ (70%) and $^{114}Sn$ (60%) targets were exposed to protons of 10 to 47 MeV from the UCLA cyclotron. The targets were shuttled between the internal beam of the cyclotron and the counting area, along a pneumatically operated rabbit system. In a single counter experiment, the gamma rays were detected by two Ge(Li) detectors of 35 cc and 3 cc, respectively, with an overall energy resolution of 3 keV for $^{60}Co$. After passing through standard pile-up rejection circuits, the pulses were digitized by 1024 channel ADC's and stored as a function of the decay time, on sequential disc files of an XSDS-925 on line computer system. The two dimensional energy versus decay time spectra thus obtained were later on brought back into core memory for energy, intensity and half-life analysis, using peak fitting routines to a gaussian shape with low energy tail.

In Fig. 1a, a 128 x 16 cut of one of these two dimensional spectra is shown. In this example, a $^{112}Sn$ target had been exposed

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†This work was supported in part by the U.S. Atomic Energy Commission.

to a 10 sec burst of 47 MeV protons, and the decay of its activity followed in 10 sec intervals. One clearly sees the 23 sec decay of the 1213 and 1245 keV gamma rays of $^{110}Sn$, the 53 sec decay of the 1258 keV line from $^{112}Sn$, and a longer lived component consisting of a mixture of the 1300 keV and 1298 keV transitions in $^{114}Sn$ and $^{116}Sn$, respectively. The accumulated sum during the first 80 sec following the bombardment is shown in Fig. 1b. The total spectrum for the next 80 sec is shown in Fig. 1c.

The isotopes produced were clearly identified by their half-life and by the threshold of the relevant (p,xn) reaction. The half-lives of the produced Sb isotopes were measured by integrating the counts below one particular gamma peak for all time intervals of the $(E_\gamma,t)$ decay spectrum. The results are shown in Fig. 2. Only the time-analysis of the strongest observed gamma transition has been plotted, for the clarity of the figures. Our results on $^{112}Sb$, $^{113}Sb$ and $^{114}Sb$ agree very well with previously reported values[1]. The half-life of $^{113}Sb$, not shown in Fig. 2, was measured to be $6.3 \pm 0.5$ min.

Coincidence experiments were then conducted using a 10 cm diameter x 10 cm thick NaI(Tℓ) and a 35 cc Ge(Li) detector. The output of these two counters was digitized by 1024 channel ADC's and stored on magnetic tape, together with their associated time-amplitude converted spectrum, (TAC) used to distinguish between real and accidental coincidences. The magnetic tape was played back into the on-line computer and 2 dimensional E(NaI) x E(Ge) arrays were formed, for particular decay times and TAC spectrum selections.

Combining the results of both experiments, most of the observed gamma transitions can be fit into a decay scheme. The energy levels obtained, accurate to 1 keV, agree very well with the results of Sn(p,d)[2,3] and Cd(α,xn) reactions[4]. These preliminary decay schemes are presented in Fig. 3 and Fig. 4, together with the relative intensity of the observed transitions which were sufficiently strong to be accurately analyzed.

Although the mass difference between the relevant Sb and Sn isotopes has not yet been measured, the measured half-lives and estimate from semi-empirical mass relationships[5] indicate clearly that most of the β decay of the investigated Sb isotopes is allowed. This calls for the following conclusions.

Levels of $J^{\pi} = 3/2^{+}$, $5/2^{+}$ but not $1/2^{+}$ are populated in $^{111}$Sn and $^{113}$Sn. This indicates that both $^{111}$Sb and $^{113}$Sb have $J^{\pi} = 5/2^{+}$. This assignment is in good agreement with a 2d 5/2 proton orbital, expected for a single proton outside a Z = 50 closed shell. Note that no isomeric level is observed in $^{111}$Sb, in agreement with the behavior of the 2d 5/2, 1g 7/2 and 3s 1/2 neutron quasi-particle energies in this region[6,7]. The second excited state of the even Sn isotopes around 2200 keV has most likely $J^{\pi} = 4^{+}$, the cross over transition to the ground state not having been observed. In this case, $^{110}$Sb, $^{112}$Sb and $^{114}$Sb have all $J^{\pi} = 3^{+}$, allowed beta decay being observed to $4^{+}$ and $2^{+}$ levels.

In order to complete the decay scheme of the Sb isotopes, β-γ, conversion electrons and beta spectrum endpoints measurements are needed. Experiments along these lines are in progress in our laboratory.

## REFERENCES


1) C.M. Lederer, J.M. Hollander and I. Perlman, Table of Isotopes, (John Wiley & Sons, Inc. 1967) and references therein.

2) E.J. Schneid, N. Prakash and B.L. Cohen, Phys. Rev. 156, 1316 (1967).

3) P.E. Cavanagh, C.F. Coleman, A.G. Hardacre, G.A. Gard and J.F. Turner, Nucl. Phys. A141, 97 (1970).

4) T. Yamazaki and G.T. Ewan, Nucl. Phys. A134, 81 (1968).

5) G.T. Garvey, W.J. Gerace, R.L. Jaffe, I. Talmi and I. Kelson, Rev. Mod. Phys. 41, 51 (1969).

6) R. Arvieu, Ann. de Phys. 8, 407 (1963).

7) L.S. Kisslinger and R.A. Sorensen, Rev. Mod. Phys. 35, 853 (1963).

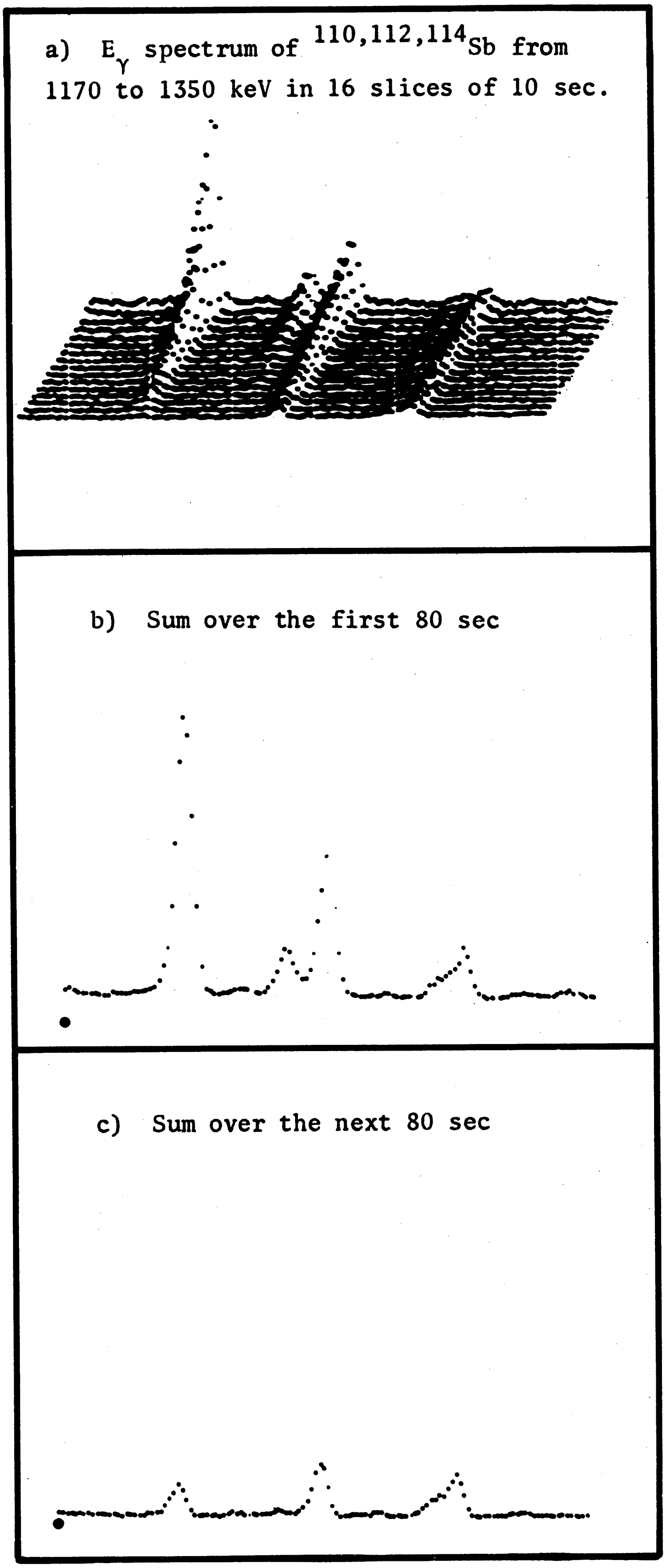

a) $E_\gamma$ spectrum of $^{110,112,114}Sb$ from 1170 to 1350 keV in 16 slices of 10 sec.
b) Sum over the first 80 sec
c) Sum over the next 80 sec

Fig. 1

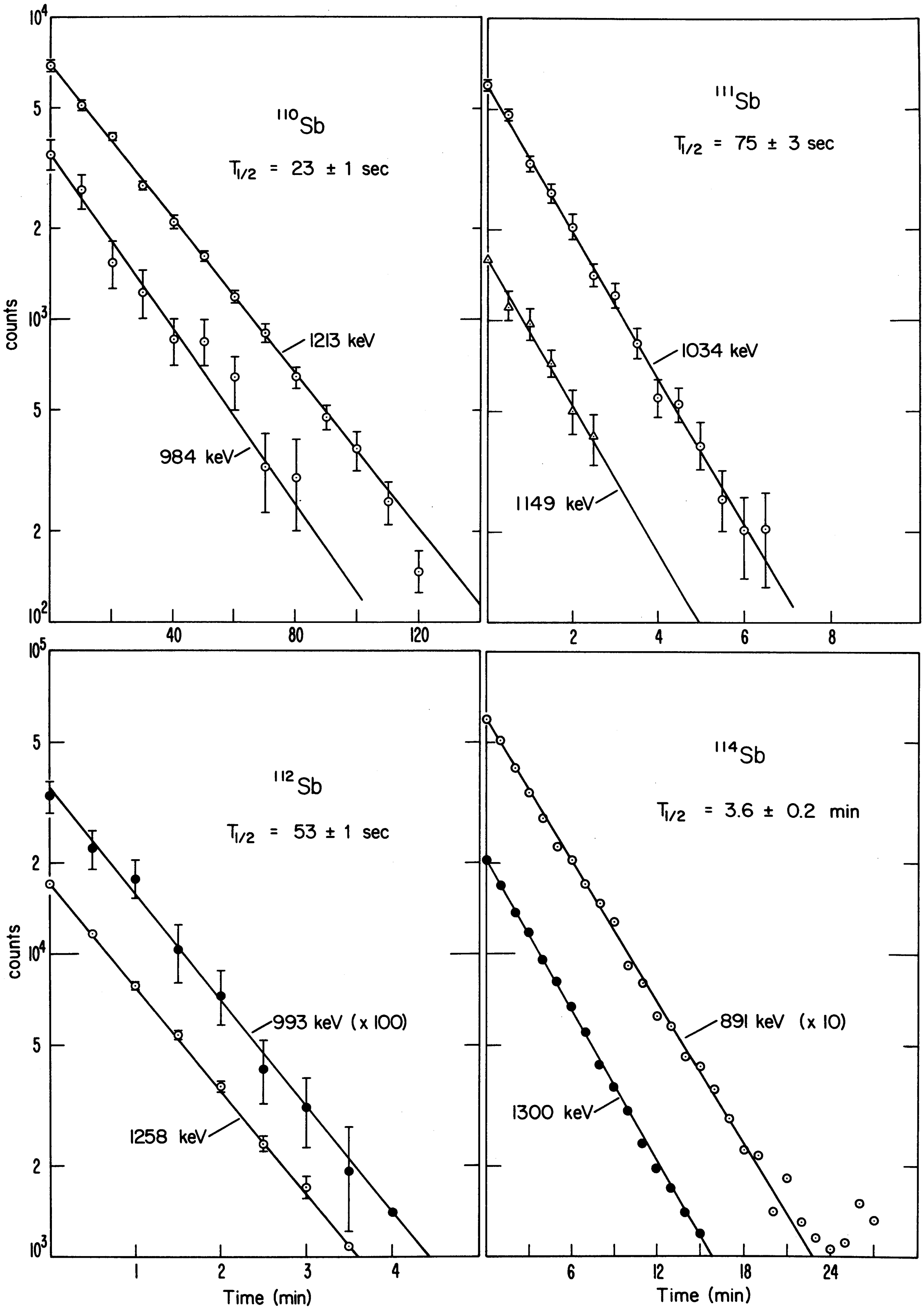
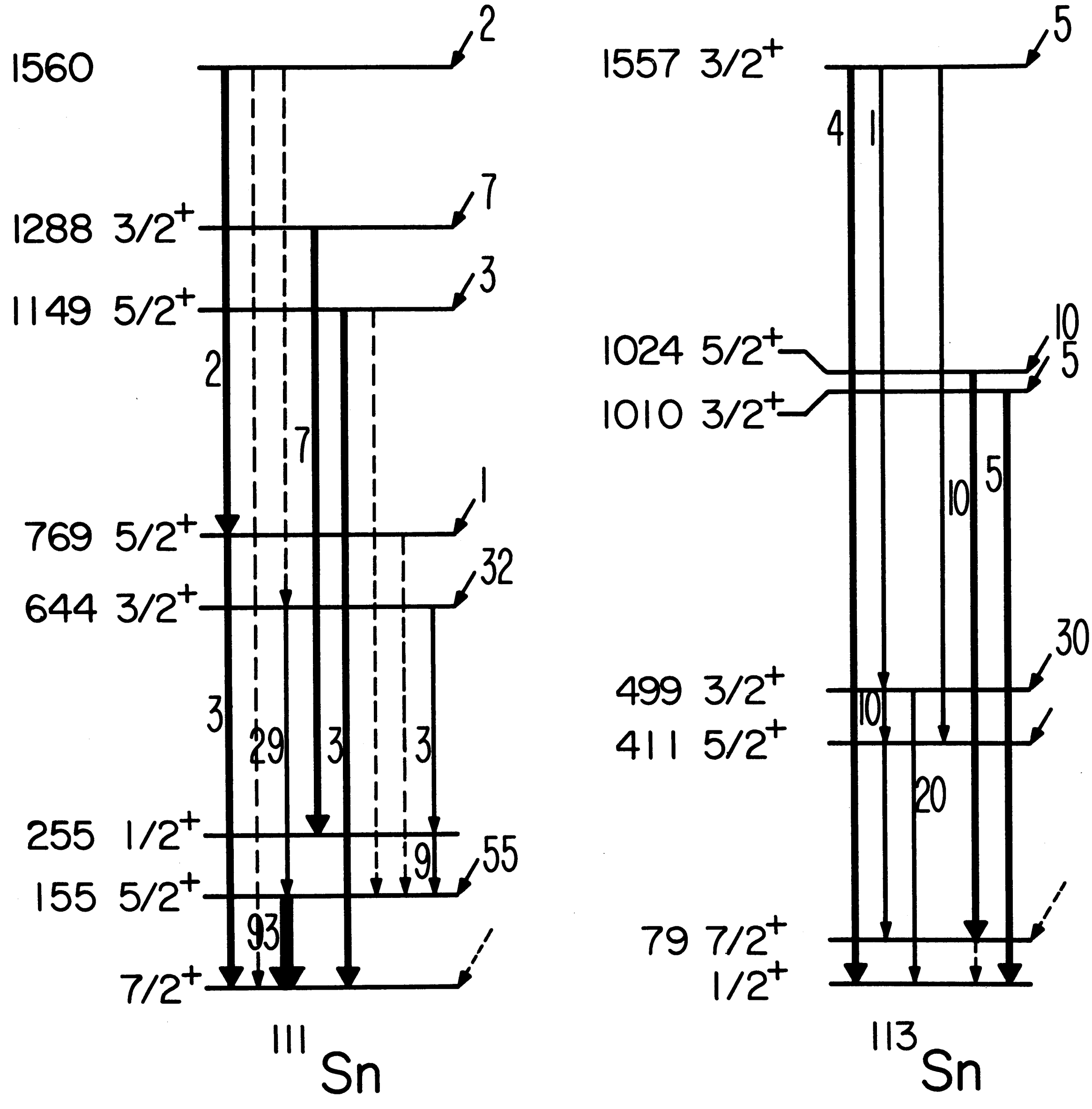
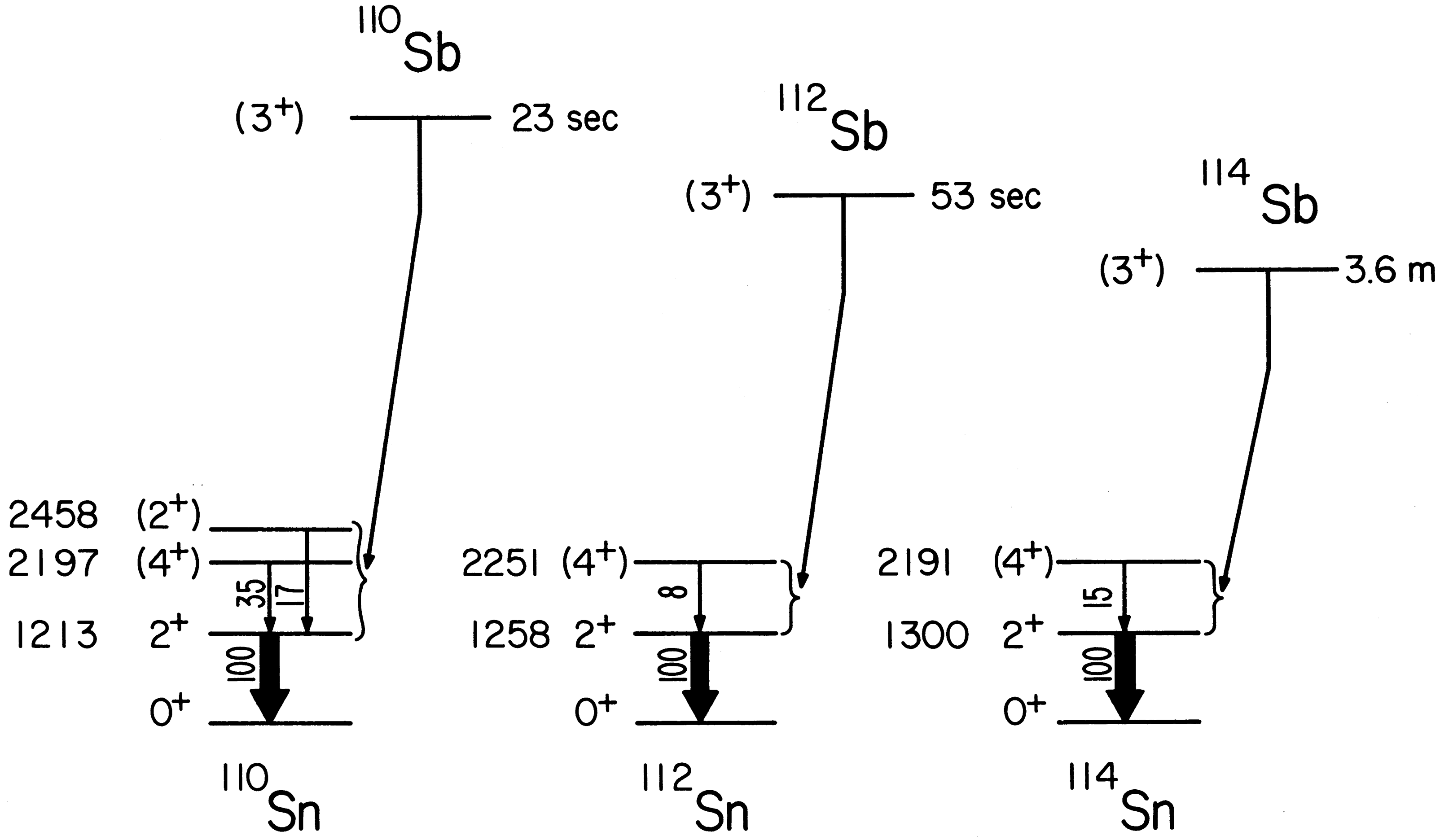



Fig. 2 Half-life curves for γ transitions in $^{110,111,112,114}$Sb.




<u>Fig. 3</u> Partial decay scheme of $^{111}$Sb and $^{113}$Sb. Relative transition intensities are indicated.




<u>Fig. 4</u> Partial decay scheme of $^{110}Sb$, $^{112}Sb$ and $^{114}Sb$.
Relative transition intensities are indicated.