Title
Relation Between Half-Life and Disintegration Energy in Orbital Electron Capture Decay

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S. G. Thompson

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RELATION BETWEEN HALF-LIFE AND DISINTEGRATION ENERGY IN ORBITAL ELECTRON CAPTURE DECAY.

By S. G. Thompson

The large amount of energy data now available for the alpha-emitters and negative beta-emitters in the heavy region makes it possible, through the medium of closed decay cycles, to calculate the total energies corresponding to a number of electron capture decay processes. Using this method, it is possible for the first time to study the relationship between disintegration energy and half-life in the electron capture process. The present note summarizes the results of a number of such calculations of decay energies and shows how these are connected with the corresponding half-lives. The data used here are taken chiefly from the recent compilation by Seaborg and Perlman.[1] The electron capture decay

(1) G. T. Seaborg and I. Perlman, Rev.Mod.Phys.20, 585 (1948).

isotope Np^{233} of 35 minute half-life, not included in the above compilation, is also used in this correlation.[2]

(2) L. B. Magnusson and G. T. Seaborg, unpublished work (Jan., 1949).

In order to illustrate the method of calculation of electron capture decay energy from a closed cycle we may consider the following:

$$\begin{array}{ccc} {}_{90}Th^{229} & \xleftarrow{K} & {}_{91}Pa^{229} \\ \alpha\downarrow & & \downarrow\alpha \\ {}_{88}Ra^{225} & \xrightarrow{\beta^-} & {}_{89}Ac^{225} \end{array}$$

It can be seen that the electron capture energy of Pa^{229} is equal to

$$E_\alpha(Pa^{229}) + E_r(Pa^{229}) - E_\alpha(Th^{229}) - E_r(Th^{229}) - E_\beta(Ra^{225})$$

where E_α corresponds to the energy of the longest range alpha-particle, E_r corresponds to the energy of recoil following alpha-emission, and E_β represents the total disintegration energy corresponding to the beta-decay process. Using the best values available we have

$$5.69 + 0.10 - 5.02 - 0.09 - 0.2 = 0.5 \text{ Mev}$$

for the electron capture disintegration energy of Pa^{229}. Since this isotope decays 99% by electron capture and 1% by alpha emission with a measured half-life of 1.5 days, this 0.5 Mev disintegration energy corresponds to a half-life of 1.5/0.99 or approximately 1.5 days.

Calculations using an extension of this method have been carried out for 16 species for which there are reliable half-life and branching data. Where the alpha-energies have not been measured they were obtained from a recent correlation between alpha-energy, mass number, and atomic number.[3] A more serious difficulty arises in estimating

(3) I. Perlman, A. Ghiorso and G. T. Seaborg, Phys.Rev. 74, 1730 (1948).

total beta-disintegration energies from the published values of the beta-particle upper energy limits and the gamma-ray energies, in that a knowledge of the disintegration scheme is necessary. The values we have chosen on which to base our calculations are summarized in the following table.

Table I.

Total Beta-Disintegration Energies of Some Heavy Isotopes

Isotope	Energy (Mev)
Bi^{213}	1.3
Ra^{225}	0.2
Pa^{233}	0.5
Pb^{211}(AcB)	1.4
Fr^{223}(AcK)	1.3
Th^{231}(UY)	0.24
Pb^{214}(RaB)	1.0
Pb^{212}(ThB)	0.6
Ra^{228}($MsTh_1$)	0.05

Fig. 1 shows a plot of the logarithm of the (partial) beta half-life versus the disintegration energy for the 16 species. Of course the partial half-life for electron capture should be related to the particular energy of the primary transition rather than to the total energy between ground states, as is plotted here, but at present only the latter values are known. It may be noticed that it is possible to draw a line to include essentially all species other than a few of the odd-odd mass type. A number of species of the odd-odd mass type follow roughly on another line corresponding to a degree of forbiddenness of a factor of the order of 10 or 100. It is interesting to note that a similar plot for a number of heavy negative beta-particle emitters, admittedly rather naive but interesting for comparison, gives two similar curves (not shown here) for the two groups of mass types. Thus the larger probability of higher spin states for odd-odd species shows up in both cases. On the same oversimplified basis, we note that both curves for electron capture decay are above the corresponding curves for beta-decay. Thus for the same disintegration energy the half-life for electron capture seems to be longer by an average factor of about 3 than the half-life for beta-decay.

It is felt that further refinements of the method presented here, in which the energy corresponding to electron capture decay to identified excited states of the product nucleus is correlated with corresponding partial half-lives, will lead to more meaningful information as to the nature of the electron capture decay process.

I am indehted to Professor Glenn T. Seaborg for many interesting and helpful discussions on this subject.

This work was performed under the auspices of the Atomic Energy Commission.

MODEL DATE

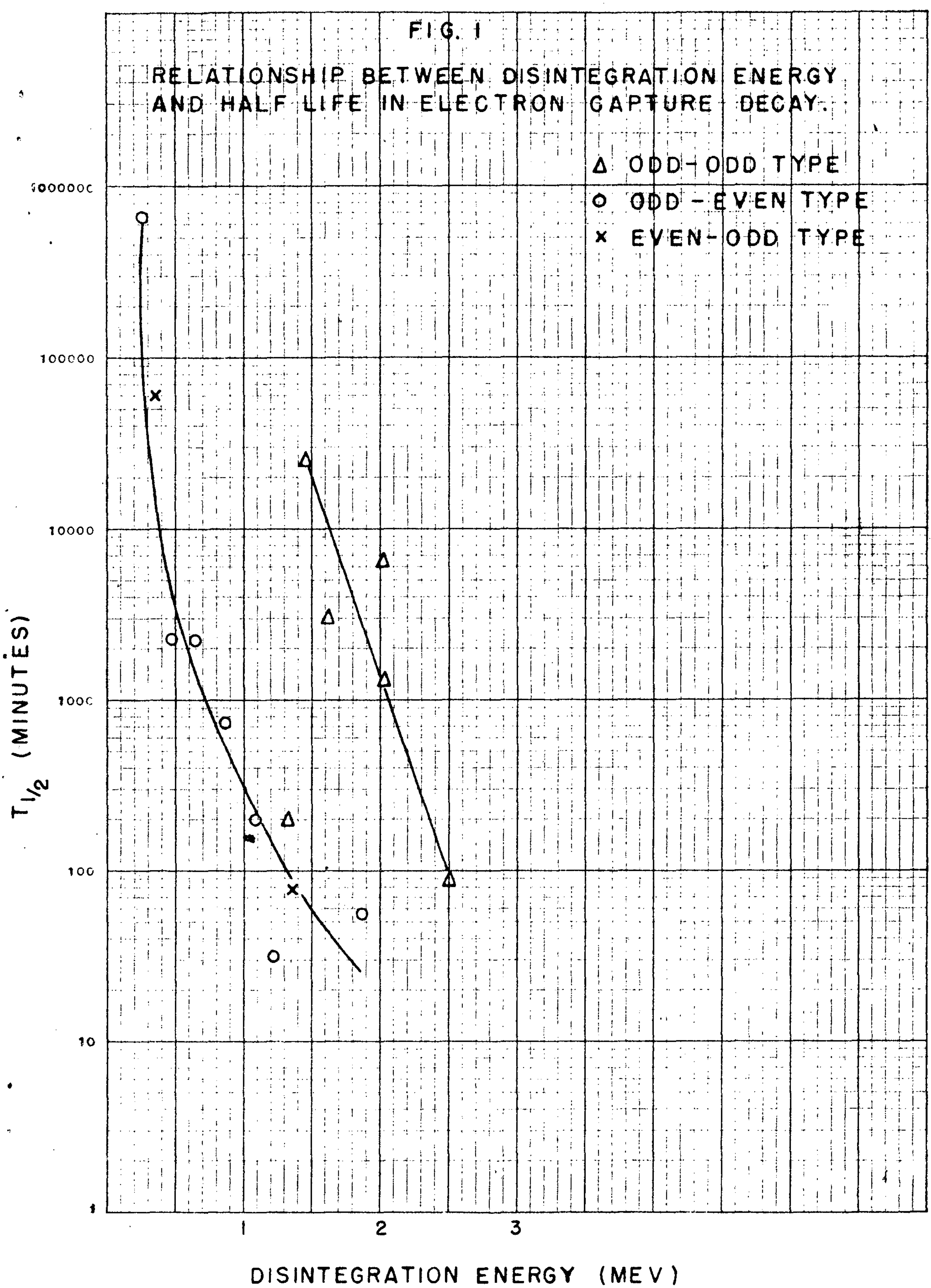

FIG. 1
RELATIONSHIP BETWEEN DISINTEGRATION ENERGY AND HALF LIFE IN ELECTRON CAPTURE DECAY.
Δ ODD-ODD TYPE
o ODD-EVEN TYPE
× EVEN-ODD TYPE
1000000
100000
10000
1000
100
10
1
1
2
3
$T_{1/2}$ (MINUTES)
DISINTEGRATION ENERGY (MEV)