

# Energy Deficit in $\beta$ Decay Process

**George J Chang**

Theoretical Physics Department

No. 1, Gong 1<sup>st</sup> Road, Cyuan Sing Industrial Park, Hemei, Changhua County,

Taiwan

E-mail: [georgejchang@aol.com](mailto:georgejchang@aol.com)

## ABSTRACT

This paper reports a constant of energy deficit of 271 keV in all  $\beta$  decay processes, when we compare the  $\beta$  decay  $Q$ -values together with the involved particles, electron and neutrino, with the calculation of the proton/neutron separation energy differences which is equivalent to the  $\beta$  decay process between mother and daughter nuclides. This result, after being verified theoretically with deduction from basic definition of proton/neutron separation energy and calculation of nuclear data with both in good agreement, implies that this energy deficit of 271 keV in all  $\beta$  decay processes is either the value of neutrino mass or, if the result of KATRIN experiment, which concluded that neutrino mass to be less than 2.05 eV, is correct, something related to undetected dark energy.

## 1. Introduction

For the purpose of easier derivation and calculation of proton/neutron separation energy and their co-relation with the equivalent  $\beta$  decay process, we show nuclides on  $Z - A$  plane instead of conventional chart of nuclides on  $Z - N$  plane. A chart of nuclides on  $Z - A$  plane with  $Z$  less than 50 and  $A$  less than 85, is shown in fig.1. Each mass number has either one or two stable isotopes in the center with positive and negative  $\beta$  decays pointing from both ends toward the center. Stable nuclides are line up and connected with bolded lines and are end products of series of positive and negative isobaric  $\beta$  decays. Co-relations among proton separation energy, neutron separation energy and the equivalent positive and negative  $\beta$  decay processes for a specific nuclide are shown in figures 2 and 3. Calculations in this paper are done basically on these two charts. It is this feature which leads to the discovery extra energy of 271 keV exists in  $\beta$  decay. It is a sign of dark energy if it is not in the form of mass of neutrino.

## 2. Correlation between nucleon separation energy and $\beta$ decay $Q$ -values on $Z$ - $A$ plane (from calculation with nuclear data)

Referring to figures 2 and 3 we can find that proton separation energy, neutron energy and  $\beta$  decay process make a triangular enclosure on  $Z$ - $A$  plane. This makes it easy for calculating their energy correlations. For a specific positive  $\beta$  decay nuclide  $(Z, A)$ , we have neutron and proton separation energy difference as below.

$$\Delta S1 = S_n(Z, A + 1) - S_p(Z, A + 1) \quad (1)$$

and

$$\Delta S2 = S_n(Z - 1, A) - S_p(Z, A), \quad (2).$$

The energy equation for  $\beta$ -decay of nuclide  $(Z, A)$  is

$$M(Z, A) - M(Z - 1, A) = Q_\beta(Z, A) + M_e + M_\nu \quad (3)$$

Since  $\Delta S1 = \Delta S2$  which are equivalent to the corresponding to  $\beta$ -decay process of nuclide  $(Z, A)$ ,

$$\Delta S1 = \Delta S2 = M(Z, A) - M(Z - 1, A) = Q_\beta(Z, A) + M_e + M_\nu \quad (4)$$

Calculation of equations (1) and (2) with nuclear data [1] showing in table 1(a), we have

$$\Delta S1 = \Delta S2 = Q_{\beta}(Z, A) + 782 \text{ keV.} \quad (5)$$

Suppose that  $M_e = 511 \text{ keV}$  and  $M_{\nu} = 0$ , equation (5) becomes

$$\Delta S1 = \Delta S2 = Q_{\beta}(Z, A) + M_e + M_{\nu} + 271 \text{ keV} \quad (6)$$

There is energy deficit of 271 keV.in equation (4) for  $\beta$ -decay process of nuclide  $(Z, A)$ , comparing with equation (6), as shown in Table 1(b).

Referring to figures 3 for a specific negative  $\beta$  decay nuclide $(Z - 1, A)$ ,

$$(Z - 1, A) \rightarrow (Z, A) + e^{-} + \text{anti-}\nu + Q_{\beta}(Z - 1, A), \quad (7)$$

$$\Delta S1 = \Delta S2 = Q_{\beta}(Z - 1, A) + M_e + M_{\nu} \quad (8)$$

Table 2(a) shows the calculation of neutron/proton separation energy relating to  $\beta$  decay of nuclide  $(Z - 1, A)$ ,

$$\Delta S1 = \Delta S2 = Q_{\beta}(Z - 1, A) + 782 \text{ keV} \quad (9)$$

Again,  $M_e = 511$  keV and  $M_\nu = 0$ , equation (9) becomes

$$\Delta S1 = \Delta S2 = Q_\beta(Z-1, A) + M_e + M_\nu + 271 \text{ keV} \quad (10)$$

Table 2(b) shows there is 271 keV of energy deficit for the selected negative  $\beta$  decay nuclides.

The calculation with nuclear data concludes that there is 271 keV of energy deficit for both positive and negative  $\beta$  decays compared with proton and neutron separation energy difference.

### **3. Correlation between nucleon separation energy and $\beta$ decay $Q$ -values on $Z$ - $A$ plane (from definition)**

The conclusion of 271 keV energy deficit in  $\beta$  decay in the previous section requires further verification and investigation, especially from theoretical point of view. Starting from the definition of proton and neutron separation energy and referring to figure 2, the neutron separation energy  $S_n(Z, A + 1)$  for nuclide  $(Z, A + 1)$  is

$$S_n(Z, A + 1) = M(Z, A) - M(Z, A + 1) + M_n, \quad (11)$$

where  $M(Z, A)$ ,  $M(Z, A + 1)$  and  $M_n$  are masses of nuclides  $(Z, A)$ ,  $(Z, A + 1)$  and neutron, respectively..

The proton separation energy  $S_p(Z, A + 1)$  for the nuclide  $(Z, A + 1)$  is

$$S_p(Z, A + 1) = M(Z - 1, A) - M(Z, A + 1) + M_p + M_e \quad (12)$$

where  $M(Z - 1, A)$ ,  $M(Z, A + 1)$ ,  $M_p$  and  $M_e$  are masses of nuclides  $(Z - 1, A)$ ,  $(Z, A + 1)$ , proton and electron, respectively.

The difference between neutron separation energy and proton separation energy

$S_n(Z, A + 1) - S_p(Z, A + 1)$ , or  $\Delta S_1$ , is

$$\Delta S_1 = M(Z, A) - M(Z, A + 1) + M_n - M(Z - 1, A) + M(Z, A + 1) - M_p - M_e \quad (13)$$

$$\Delta S_1 = M(Z, A) + M_n - M(Z - 1, A) - M_p - M_e \quad (14)$$

Referring to fig. 3, if  ${}^A_{Z-1}X$  undergoes negative  $\beta$  decay by emitting one electron

and

one anti-neutrino,  ${}^A_{Z-1}X$  becomes  ${}^A_ZY + M_e + M_{\bar{\nu}}$  -  $Q_{\beta}({}^A_{Z-1}X)$

and

equation (13) becomes

$$\Delta S1 = M({}^A_ZY) + M_n - [M({}^A_ZY) + M_e] - M_e - M_{\bar{\nu}} + Q_{\beta}({}^A_{Z-1}X) - M_p - M_e$$

(15)

or

$$\Delta S1 = M_n - M_{\bar{\nu}} + Q_{\beta}({}^A_{Z-1}X) - M_p - M_e$$

(16)

Substituting  $M_n - M_p$  with  $M_e + M_{\bar{\nu}} + 782 \text{ keV}$ , Eq. (16) becomes

$$\Delta S1 = Q_{\beta}({}^A_{Z-1}X) + 782 \text{ keV}$$

(17)

Theoretical deduction agrees with calculation with nuclear data, equation (17) is exactly the same as it shows in figure 3 or equation (9)..

Also from definition, neutron separation energy  $S_n(Z-1, A)$  for nuclide  $(Z-1, A)$  is

$$S_n(Z-1, A) = M(Z-1, A-1) - M(Z-1, A) + M_n \quad (18)$$

and proton separation for nuclide  $(Z, A)$ ,

$$S_p(Z, A) = M(Z-1, A-1) - M(Z, A) + M_p - M_e \quad (19)$$

The difference between neutron separation energy and proton separation energy,  $\Delta S2$ , is

$$\Delta S2 = M(Z-1, A-1) - M(Z-1, A) + M_n - M(Z-1, A-1) + M(Z, A) - M_p - M_e \quad (20)$$

or

$$\Delta S2 = -M(Z-1, A) + M_n + M(Z, A) - M_p - M_e \quad (21)$$

which is exactly the same as equation (14) so that  $\Delta S2 = \Delta S1$ .

Referring to fig. 2, if  $\square(Z, A)$  undergoes positive  $\beta$  decay by emitting one positron and

one neutrino,  $\square M \square(Z, A)$  becomes  $[M(Z-1, A) + M_e] + M_e + M_\nu + Q_\beta(\square Z, A)$  and equation

(15) becomes

$$\Delta S1 = M(Z-1, A) + 2M_e + M_\nu + Q_\beta(\square Z, A) + M_n - M \square(Z-1, A) - M_p - M_e$$

(22)

or

$$\Delta S1 = M_e + M_\nu + Q_\beta(\square Z, A) + M_n - M_p$$

(23)

Since  $\beta$  decay of neutron is negative which is a reversal process, we substitute  $\square M_n - M_p$

with  $-M_e - M_\nu - (-782 \text{ keV})$  and Eq. (23) becomes

$$\Delta S1 = M_e + M_\nu + Q_\beta(\square Z, A) - M_e - M_\nu - (-782 \text{ keV})$$

(24)

or

$$\Delta S1 = Q_\beta(\square Z, A) + 782 \text{ keV}$$

(25)

Equation (25) is exactly the result of figure 2 so that the result of calculation with nuclear data of neutron and proton separation energies is proved to be in good agreement with the theory. There truly exists some undetected energy of 271 keV in  $\beta$  decay.

#### **4. Discussion and conclusion**

The Standard Model of particle physics presumes that neutrino is with zero mass but physical experiments find that neutrinos oscillate in flavor and require possessing mass [2]. The SuperKmiokande experiment in, KATRIN experiment, concluded the neutrino mass  $< 2.05$  eV (95% C.L.), for Troitsk experiment [3, 4], and  $< 2.3$  eV (95% C.L.), for Mainz experiment [5]. This result, although advocates neutrino with mass, clashes with the conclusion of this paper in value, in the order of a few electron volt to 271 keV. If the value of KATRIN experiment is accepted, the only possible solution for the energy deficit in  $\beta$  decay is dark energy which is yet to be detected. The energy deficit is so unambiguous that either neutrino mass or the dark energy is the solution..

## REFERENCES

[1] S.Y.F. Chu, L.P. Ekstrom and R.B. Firestone. The Lund/LBNL Nuclear Data Search, Version

2.1, January 2004.

[2] Fukuda Y, *et al.* (1998) Physical Review Letters, **81** (6): 1158 – 1162.

[2] G.C. McLaughlin, J.N. Ng, Phys Rev. **D63** (2001) 053002

[3] V. M. Lobashev, Proc. 17. Int. Conf. Nuclear Physics in Astrophysics,

Debrecen/Hungary, 2002, *Nucl. Phys.* **A719**, 153c (2003)

[4] H. Georgi, S.L. Glashow, Phys. Rev. **D61** (2000) 097301

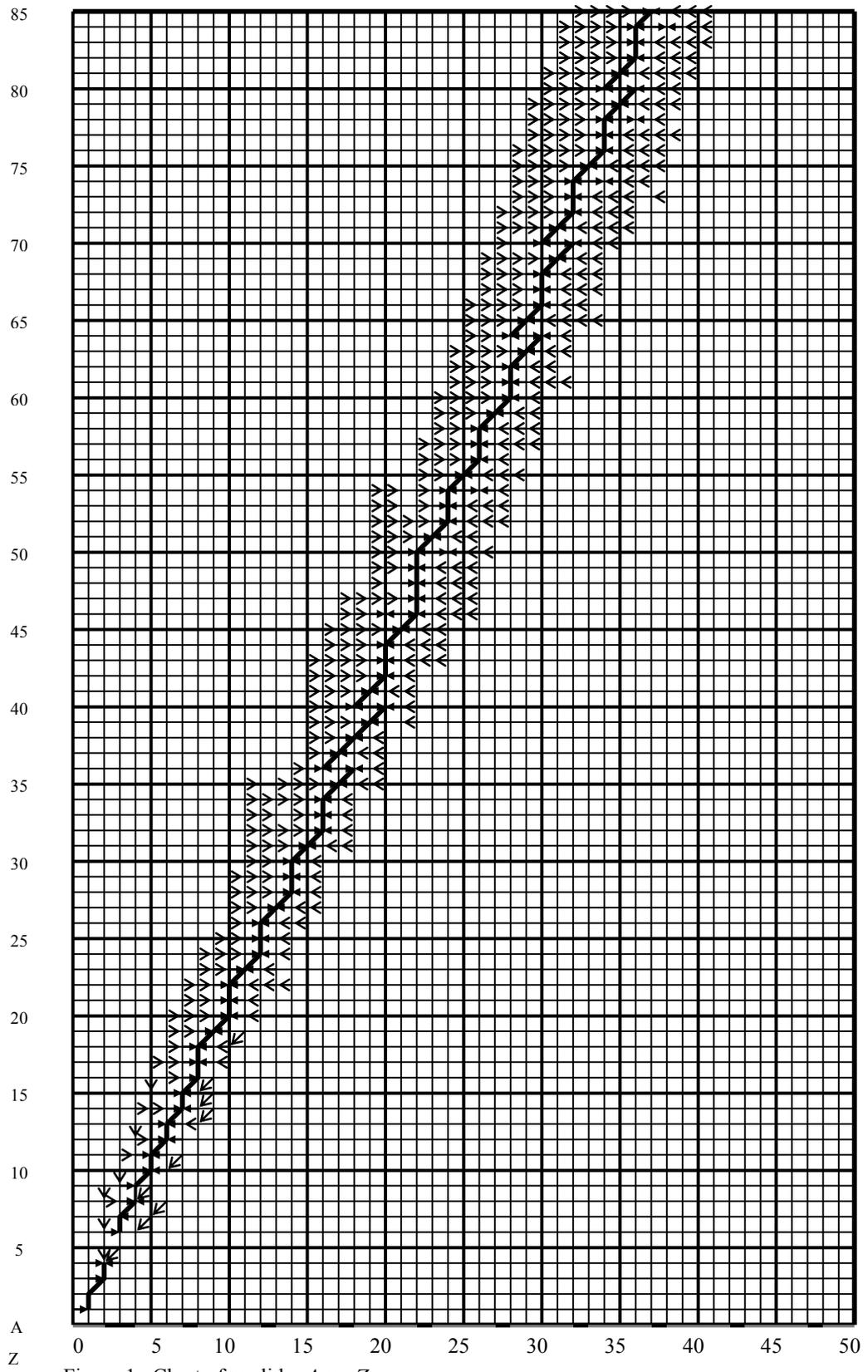
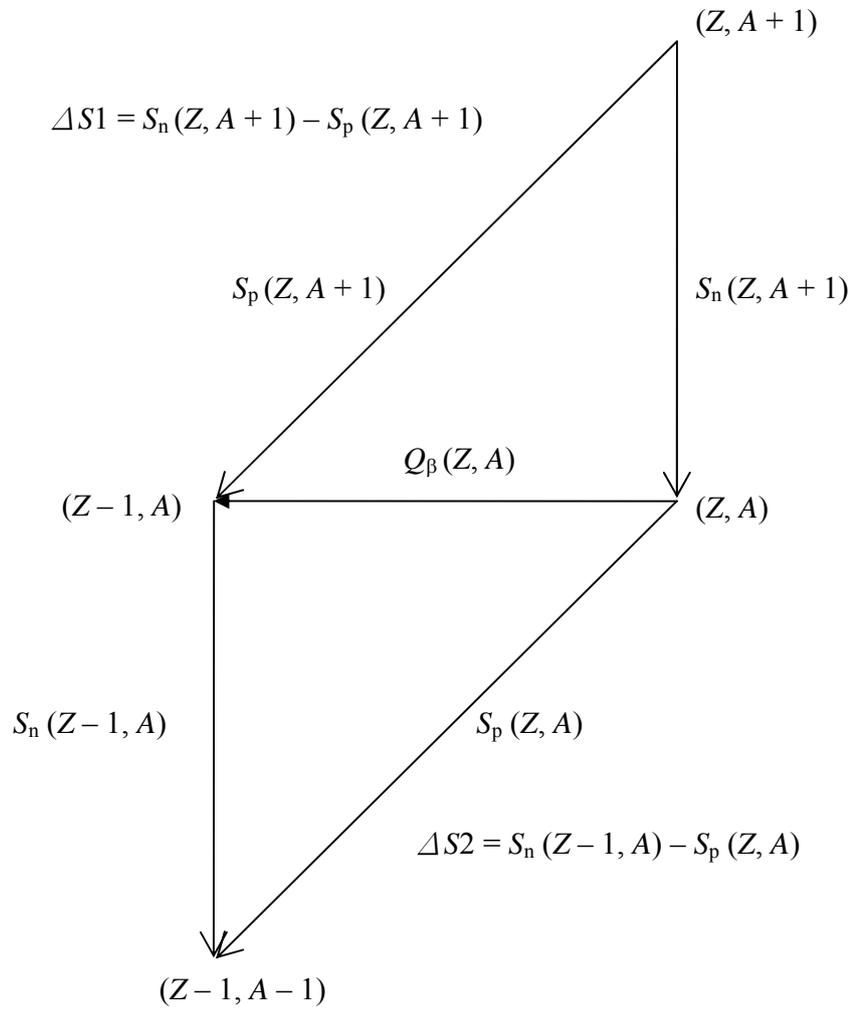


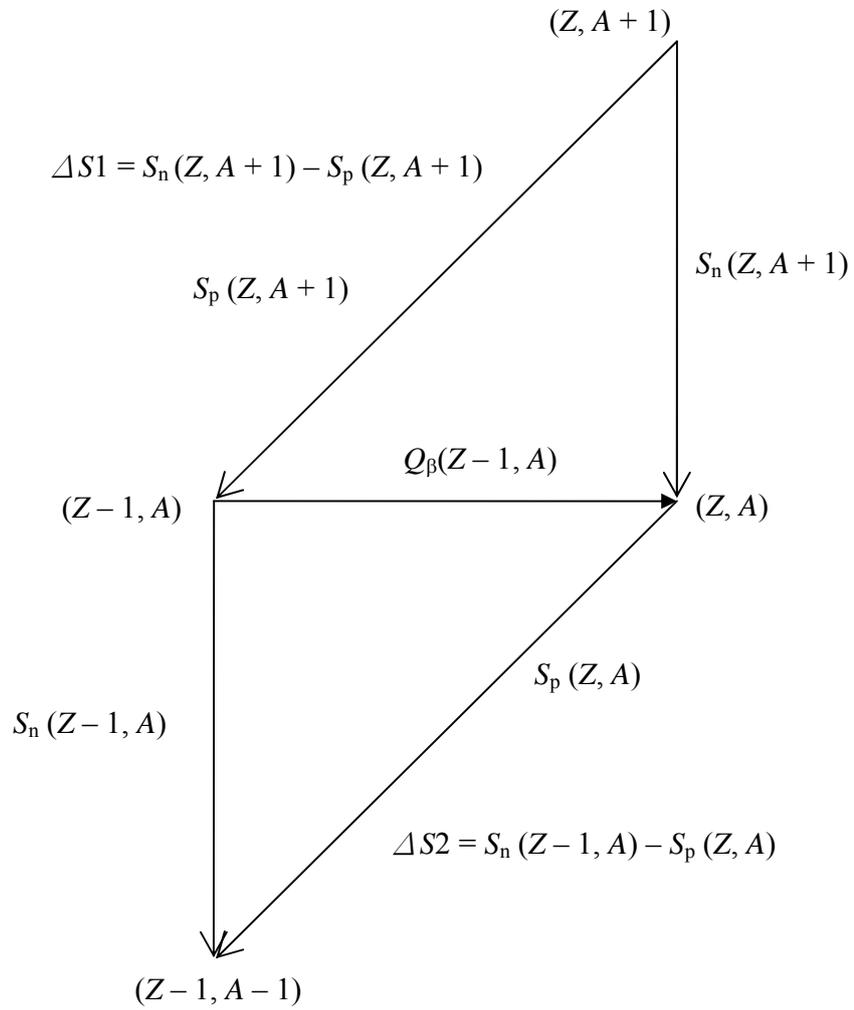
Figure 1 Chart of nuclides A vs. Z



$$\Delta S1 = \Delta S2 = Q_\beta(Z, A) + 782 \text{ keV} > 782 \text{ keV},$$

$$\text{or } Q_\beta(Z, A) > 0$$

Figure 2



$$\Delta S 1 = \Delta S 2 = Q_\beta(Z - 1, A) + 782 \text{ keV} < 782 \text{ keV}$$

$$\text{or } Q_\beta(Z, A) < 0$$

Figure 3

**TABLE 1(a)**

(Z, A)	$S_n(Z, A+1)$ (1)	$S_p(Z, A+1)$ (2)	(1) - (2) $\Delta S 1$	$S_n(Z-1, A)$ (3)	$S_p(Z, A)$ (4)	(3) - (4) $\Delta S 2$	$Q_\beta(Z, A)$ (5)	$\Delta S 1 - (5)$	$\Delta S 2 - (5)$
(32, 64)	10100	4860	5240	10220	5000	5220	4410	830	810
(31, 64)	11890	3942	7948	11862	3914	7948	7165	783	783
(29, 64)	9910	7453	2457	9658	7201	2457	1675	782	782
(32, 63)	15600	5000	10600	12760	2200	10560	9780	820	780
(31, 63)	10220	3914	6306	9113	2810	6303	5520	786	783
(30, 63)	11861	7712	4149	10853	6704	4149	3367	782	782
(31, 62)	12760	2810	9950	12896	2810	10086	9170	780	916
(30, 62)	9113	6704	2409	8886	6477	2409	1627	782	782
(29, 62)	10853	6122	4731	10597	2810	4730	3948	783	782
(30, 61)	12896	6477	6419	11710	5290	6420	5637	782	783
(29, 61)	8886	5867	3019	7820	4800	3020	2237	782	783

(All values in keV)

Referring to figure 2, calculation of nuclear data indicate correlations among nucleon separation energies and beta decay  $Q$ -values for selected positive beta decays, referring to figure 2, as

$$\Delta S 1 = \Delta S 2 = Q_\beta(Z, A) + 782 \text{ keV},$$

where  $\Delta S > 782 \text{ keV}$ .

**TABLE 1(b)**


---

$(Z, A)$	$\Delta S 1$	$\Delta S 2$	$Q_{\beta}(Z, A) + M_e + M_{\nu}$ $M_e = 511, M_{\nu} = 0$	$\Delta S 1$ excessive	$\Delta S 2$ excessive
(32, 64)	5240	5220	4921	319	299
(31, 64)	7948	7948	7676	272	272
(29, 64)	2457	2457	2186	271	271
(32, 63)	10600	10560	10291	309	269
(31, 63)	6306	6303	6031	275	272
(30, 63)	4149	4149	3878	271	271
(31, 62)	9950	10086	9681	269	405
(30, 62)	2409	2409	2138	271	271
(29, 62)	4731	4730	4459	272	271
(30, 61)	6419	6420	6148	271	272
(29, 61)	3019	3020	2748	271	272

---

(All values in keV)

Referring to figure 2, the same list of nuclides as table 1(a), differences of neutron and proton energies,  $\Delta S 1$  as well as  $\Delta S 2$  is 271 keV excessive comparing with  $Q_{\beta}(Z, A) + M_e + M_{\nu}$ , where  $M_e = 511$  and  $M_{\nu} = 0$

**TABLE 2(a)**

(Z, A)	$S_n(Z, A + 1)$ (1)	$S_p(Z, A + 1)$ (2)	(1) – (2) $\Delta S 1$	$S_n(Z - 1, A)$ (3)	$S_p(Z, A)$ (4)	(3) – (4) $\Delta S 2$	$Q_\beta(Z - 1, A)$ (5)	$\Delta S 1 - (5)$	$\Delta S 2 - (5)$
(29, 64)	7980	7776	204	7916	7712	204	-579	783	782
(27, 64)	6020	12548	-6528	6020	12548	-6528	-7307	779	779
(26, 64)	7446	11400	-3959	7400	11300	-3900	-4700	741	800
(25, 64)	4300	15500	-11200	4400	15600	-11200	-12000	800	800
(28, 63)	7916	7201	715	6838	6122	716	-67	782	783
(27, 63)	9658	12548	-2890	8480	11370	-2890	-3672	782	782
(26, 63)	6020	11300	-5280	4950	10228	-5278	-6060	780	782
(25, 63)	7400	15600	-8200	6400	14600	-8200	-9000	800	800
(27, 62)	6838	11370	-4532	6604	11137	-4533	-5315	783	782
(26, 62)	8480	10228	-1748	8052	9800	-1748	-2530	782	782
(25, 62)	4950	14600	-9650	4800	14500	-9700	-10400	750	700
(27, 61)	10597	11137	-540	9322	9862	-540	-1322	782	782
(26, 61)	6604	9800	-3196	5582	8777	-3195	-3978	782	783
(25, 61)	8052	14500	-6448	6900	13300	-6400	-7200	752	800
(1, 3)	20578	19814	764	6257	5493	764	-19	783	783
(1, 1)	0	0	0	2225	2225	0	-782	782	782

(All values in keV)

Referring to figure 3, the correlation for selected negative beta decays is

$$\Delta S 1 = \Delta S 2 = Q_\beta(Z, A) + 782 \text{ keV},$$

where  $\Delta S < 782 \text{ keV}$  , including neutron beta decay for which  $\Delta S = 0$  and  $Q_\beta = 782 \text{ keV}$ .

**TABLE 2(b)**


---

$(Z, A)$	$\Delta S 1$	$\Delta S 2$	$Q_{\beta}(Z, A) + M_e + M_{\nu}$ $M_e = 511, M_{\nu} = 0$	$\Delta S 1$ excessive	$\Delta S 2$ excessive
(29, 64)	204	204	-68	272	272
(27, 64)	-6528	-6528	-6796	268	268
(26, 64)	-3959	-3900	-4189	230	289
(25, 64)	-11200	-11200	-11489	289	289
(28, 63)	715	716	444	271	272
(27, 63)	-2890	-2890	-3161	271	271
(26, 63)	-5280	-5278	-5549	269	271
(25, 63)	-8200	-8200	-8489	289	289
(27, 62)	-4532	-4533	-4804	272	271
(26, 62)	-1748	-1748	-2019	271	271
(25, 62)	-9650	-9700	-9889	239	189
(27, 61)	-540	-540	-811	271	271
(26, 61)	-3196	-3195	-3467	271	272
(25, 61)	-6448	-6400	-6689	241	289
(1, 3)	764	764	492	272	272
(1, 1)	0	0	-271	271	271

---

(All values in keV)

Referring to figure 3, the same list of nuclides as table 2(a), differences of neutron and proton energies,  $\Delta S 1$  as well as  $\Delta S 2$  is 271 keV excessive comparing with  $Q_{\beta}(Z, A) + M_e + M_{\nu}$ , where  $M_e = 511$  and  $M_{\nu} = 0$

## CAPTIONS for figures

### Figure 1

Nuclides are arranged on the plane  $A$  against  $Z$  for  $A$  less than 85 and  $Z$  less than 50. Isobars decay through beta transition to the stable and least massive nuclide in the middle for each  $A$ . Stable isotopes line up in the beta-stable “valley.” Each  $A$  has only one stable nuclide except at where the line shift two  $Z$  units less, causing that number of  $A$  has two stable isobars. Bold line segments connect beta-stable nuclides in the “valley.”

### Figure 2 Positive beta decay

We expect  $\Delta S_1 = \Delta S_2 = Q_\beta(Z, A) + 511 \text{ keV}$ . However, nuclear data calculation indicate that  $\Delta S_1 = \Delta S_2 = Q_\beta(Z, A) + 782 \text{ keV}$ , when  $\Delta S > 782 \text{ keV}$ .

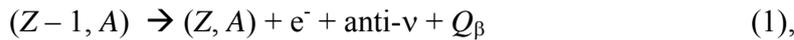
### Figure 3 Negative beta decay.

We expect  $\Delta S_1 = \Delta S_2 = Q_\beta(Z, A) + 511 \text{ keV}$  but nuclear data calculation indicate that  $\Delta S_1 = \Delta S_2 = Q_\beta(Z, A) + 782 \text{ keV}$ , when  $\Delta S < 782 \text{ keV}$ .

# Energy distribution of $\beta$ -decay electrons and neutrinos

The kinetic energy distribution of electron of beta decay, as shown in figure 1, contains no information of any clues to determine the mass of electron, not to mention the mass of neutrino or anti-neutrino. This is the major flaw of current direct neutrino mass experiments determining neutrino/antineutrino mass by beta spectrum deviation at the endpoint of tritium beta decay spectrum because the electron mass is not a decisive factor of the characteristic kinetic energy spectrum for beta decay electrons, neither is the neutrino/antineutrino mass.

Typical  $\beta$ -decay of nuclei is



and the energy distribution of electrons of beta decay looks like as fig.1.

The sum of kinetic energies of electron  $E_e$ , and anti-neutrino  $E_\nu$ , for a particular beta decay should be with relationship as below.

$$E_e + E_\nu = Q_\beta \quad (2)$$

This means that for every electron with kinetic energy value  $E_e$  in the spectrum in fig.1, there is a corresponding anti-neutrino with kinetic energy with value  $E_\nu$ , where

$$E_\nu = Q_\beta - E_e \quad (3)$$

i.e., number of each specific electron kinetic energy  $E_e$  in spectrum, there is the same number of anti-neutrino with kinetic energy with value  $E_\nu$ , where  $E_e + E_\nu = Q_\beta$ . The distribution of energy spectrums of electrons anti-neutrinos are thus deduced as in fig. 2 respectively.

There is no clue of values of electron and neutrino mass in the energy distribution of beta decay and the result of KATRIN experiment is the deviation of the Q-value of Tritium beta decay, rather than the value of the anti-neutrino mass. 271 keV should be the evidence of value of neutrino mass.

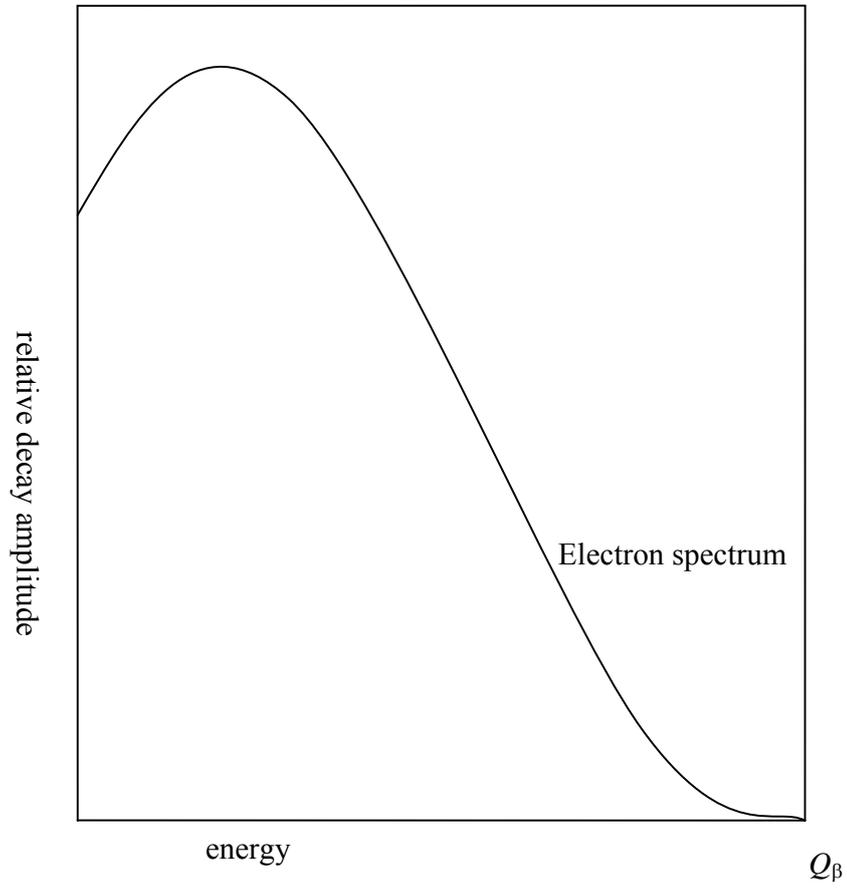


Figure 1

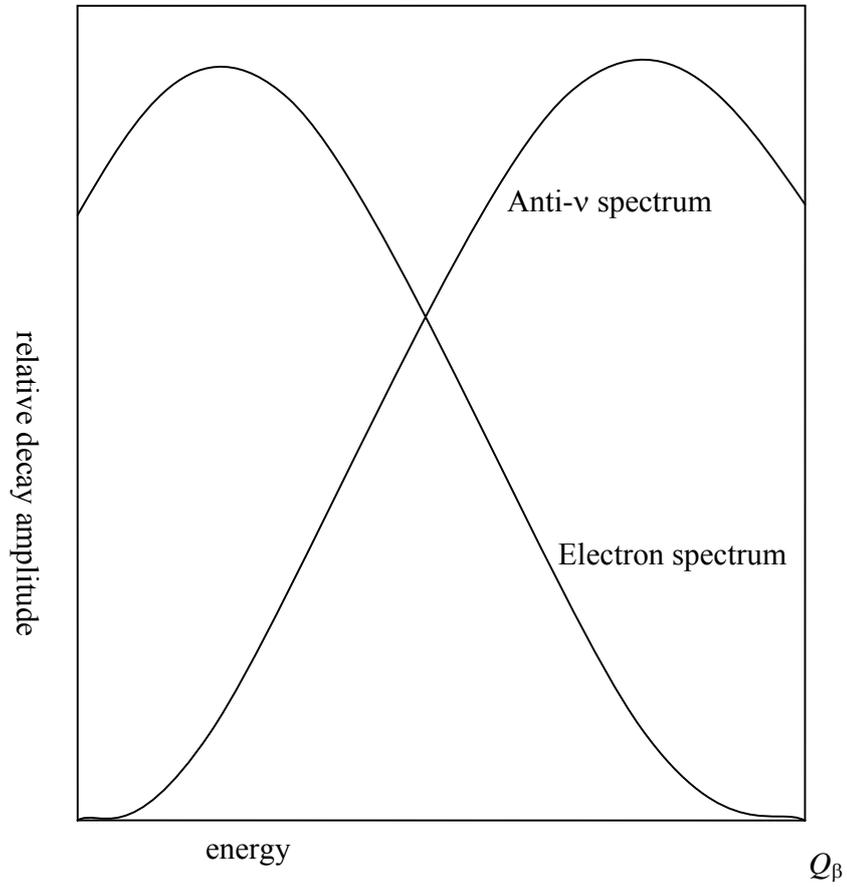


Figure 2