Theoretical study of Energy Levels for $^{176}_{70}$Yb Isotope by using Rapid Method

Musa Kadhim Mohsin Al-Oujani
Physics Dept.- College of Science - Babylon University-Iraq
-

Jumana K. Buraihi Al-Zamily
Physics Dept.- College of Science - Babylon University-Iraq.
jumana _alzamily @yahoo.com

Abstract:

The research is include theoretical study of the properties of the low-lying energy states of $^{176}_{70}$Yb isotope. calculation of the energies of the end point of the levels of $^{176}_{70}$Yb isotope feeders transitions negative beta as well as account the branching ratios (B.R%) of these levels and through this information been identified comparative half-life ($Log\ ft$) of each of these levels by using the rapid method of nuclear levels, which depends on the energy levels and the half-life of the parent nucleus and its atomic number (Z) and compare it with previous studies which found that there is a good agreement with these results.

Keywords: Energy Levels , Branching Ratio **,** Log ft.

دراسة نظرية لمستويات الطاقة لنظير الإيتيربيوم $^{176}_{70}$Yb بإستعمال ألطريقة ألسريعة

موسى كاظم محسن العوجاني
قسم الفيزياء، كلية العلوم، جامعة بابل

جمـانه كـريم بريهي الزامـلـي
قسم الفيزياء، كلية العلوم، جامعة بابل

الخلاصة:

تم حساب طاقات نقطة النهاية لمستويات النظير المشع الإيتيربيوم ($^{176}_{70}$Yb) المتغذية بإنتقالات بيتا السالبة وكذلك تم حساب نسب التفرع (B. R%) لهذه المستويات ومن خلال هذه المعلومات تم تحديد اعمار النصف المقارنة (Log ft) لكل مستوي من هذه المستويات باستعمال الطريقة السريعة للمستويات النووية والتي تعتمد على طاقة المستويات وعمر النصف للنواة الام والعدد الذري (Z) لها ومقارنتها مع الدراسات السابقة حيث وجد بأن هناك تطابقاً جيداً مع هذه النتائج.

الكلمات المفتاحية: مستويات الطاقة ،نسبة التفرع،اعمار النصف المقارنة (Log ft).

1. Introduction

Ytterbium is a chemical element with symbol Yb and atomic number 70, Natural ytterbium is composed of seven stable isotopes: $^{168}_{70}$Yb, $^{170}_{70}$Yb , $^{171}_{70}$Yb, $^{172}_{70}$Yb , $^{173}_{70}$Yb , $^{174}_{70}$Yb , and $^{176}_{70}$Yb, with $^{174}_{70}$Yb being the most abundant isotope, at 31.8% of the natural abundance. 27 radioisotopes have been observed, with the most stable ones being $^{169}_{70}$Yb with a half-life of 32.0 days, $^{175}_{70}$Yb with a half-life of 4.18 days, and $^{166}_{70}$Yb with a half-life of 56.7 hours. All of its remaining radioactive isotopes have half-lives that are less than two hours and most of these have half-lives are less than 20 minutes [1,2].

In nuclear physics, beta decay (β-decay) is a type of radioactive decay in which a proton is transformed into a neutron, or vice versa, inside an atomic nucleus [3]. This process allows the atom to move closer to the optimal ratio of protons and neutrons. As a result of this transformation, the nucleus emits a detectable beta particle, which is an electron or positron [3].There are two types of beta decay, known as beta minus and beta plus. Beta minus (β^-) decay produces an electron and antineutrino, while beta plus (β^+) decay produces a positron and neutrino; β^+decay is thus also known as positron emission [4]. A neutrino is formed at the same time that the neutron is formed, and energy carried off by it serves to conserve momentum. Any energy that is available due to the atomic mass of the product being appreciably less than that of the parent will appear as gamma radiation [4]. In this research was used quick way to calculate the reconstruction of the comparative half where this method planners first and which consists of three columns of containing a, b, c, and includes a column of two sets of energy values (E_0), where the applied values on the right side in the case of the emission of ($\beta^\mp$), which represents maximum kinetic energy ($E_\beta^\pm$) for beta particles and in units MeV and aren't included static mass values. As the left side, they are applied in the case of k-capture to the atomic level k. The second scheme, it reads (Log c) of curve fitting of beta emission [5].

The beta spectrum is a continuous spectrum: the total decay energy is divided between the electron and the antineutrino [6].

2. Comparative half-life:

Half-life is a mathematical and scientific description of exponential or gradual decay.We have fixed formula known as beta decay, which can be known probability of decay.

The Constant rate of decay equal to the inverted age (τ) as following equation [7]:

$$\lambda = \frac{1}{\tau} = \frac{|M_{fi}|^2}{\tau} f(E,Z) \qquad (1)$$

The value of ($|M_{fi}|^2$) possibility of dissolution of up to zero when transfer prohibited.

$f(E,Z)$ is the Fermi function that describes the effect of the Coulomb field of the nuclei of the beta particle emitted and this function is heavily dependent on energy end-point (E).

The half-life ($t_{1/2}$) for dissolution can be written in terms of the decay constant as follows [7]:

$$t_{1/2} = \frac{\ln 2}{\lambda} = \frac{\tau \ln 2}{|M_{fi}|^2} \frac{1}{f(E,Z)} \qquad (2)$$

$$ft = t_{1/2} \,.\, f(E,Z) = \frac{\tau \ln 2}{|M_{fi}|^2} \qquad (3)$$

(ft) value which is equal to the product of the half-life function Fermi called half-life comparison and change its value from ($10^2 \dashrightarrow 10^{23}$) second, Therefore we use the value (Log ft) instead of (ft).

3. Calculation of Levels Properties:

Since the comparative β -decay half-life or (ft) value was first introduced by Konopinski [8], spin and parity assignment for nuclear energy levels have been made on the basis of Log ft values. $Log\ (ft)$ can be written as the sum of three additive terms [5]:

$$Log\ ft = Logc + Logf_o t + \Delta Logft \qquad (4)$$

The first term, $Logc$ was obtained using the figure (3-1) [9-11], depending on the values of the end point energies of the beta decay (E_{β^-}) in MeV units and the atomic number ($= 69$) of the parent nucleus. The second term, also obtained using the figure (3-2) [9-11] , depending on the values of the (E_{β^-}) in MeV units and the half-life time ($T_{1/2} = 1.9\, min$) of the parent nucleus.

While the third term was obtained from the following relation [5]:

$$\Delta\, Logft = 2 - Log(B.R\%) \qquad (5)$$

Where ($B.R\%$) is the branching ratios were obtained from the gamma rays balance between transitions feeding and depopulating levels.

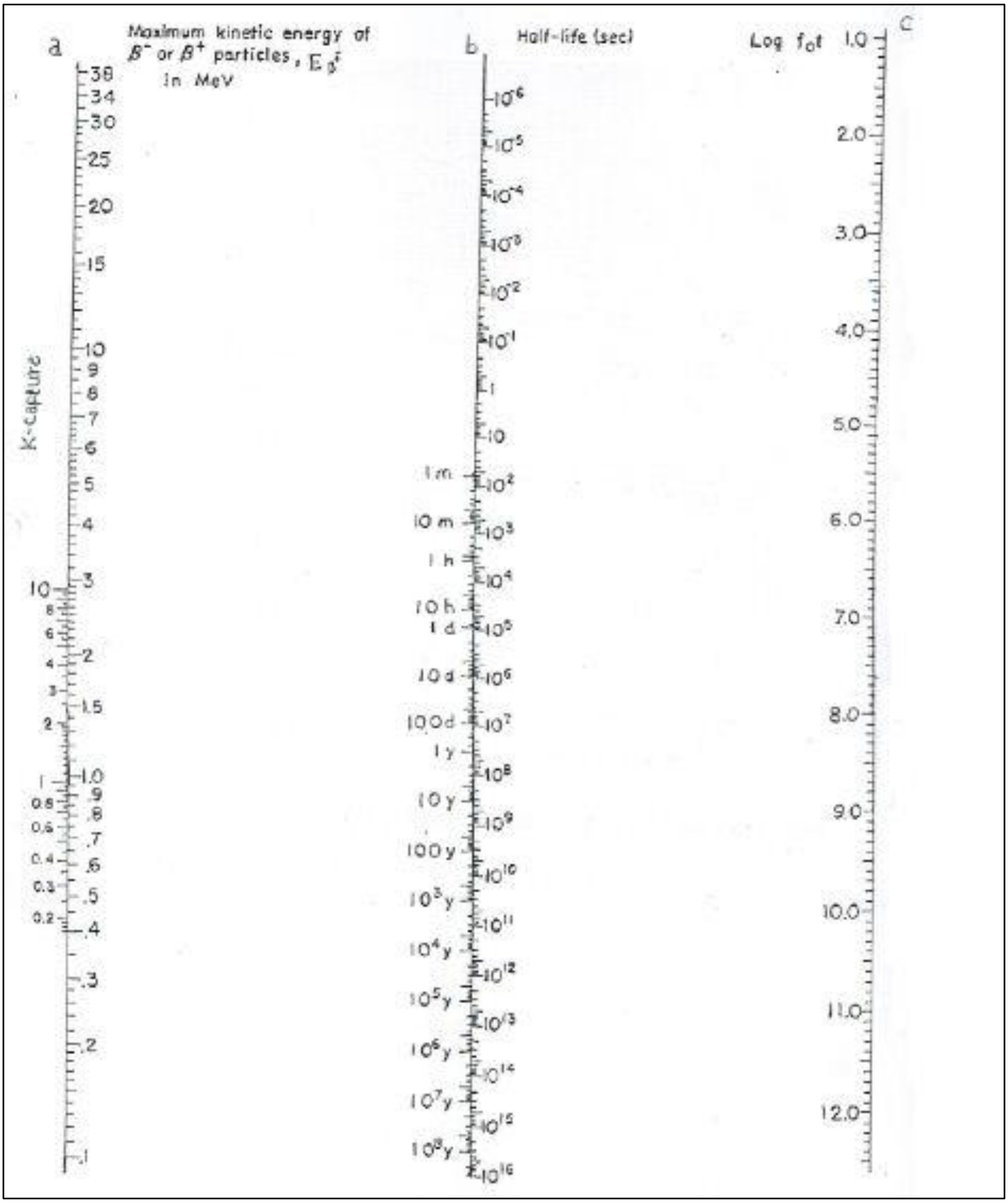

Figure (3-1) shows the values of (Log $f_0 t$) corresponding to the values of ($E_\beta^\mp$) and half-life ($t_{1/2}$)[9-11]

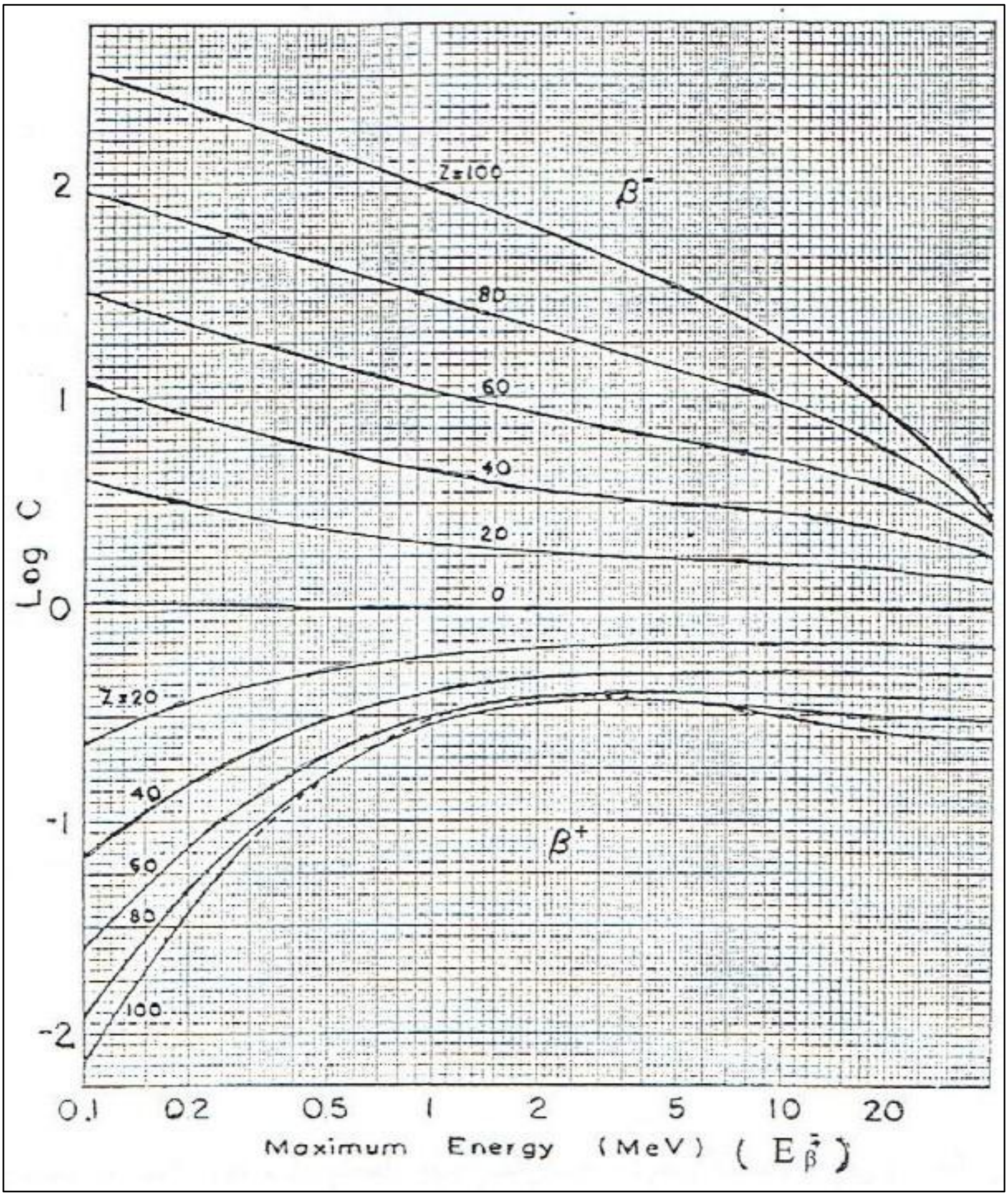

Figure (3-2) shows the values of (Log c) corresponding to the values of ($E_\beta^\mp$) [9-11]

The end point energies (E_{β^-}) of the beta decay (β^-) were calculated using the following equation [12]:

$$E_{\beta^-} = Q_{\beta^-} - E_{level} \qquad (6)$$

Where(Q_{β^-}) is the disintegration energy equal to (4120 KeV) [13,14], and E_{level} is the energy levels of the $^{176}_{70}$Yb nucleus.

The (E_{β^-}) values and its feeding branching ratios ($B.R\%$) for each level of $^{176}_{70}$Yb are given in Table (1). The $Log\,ft$ for each level of $^{176}_{70}$Yb are given in Table (2)

Table (1) The branching ratios (B.R %) Values Assignment for $^{176}_{70}Yb$ Isotope Levels

Energy level(KeV)	$E_{\bar{\beta}}$ (KeV)	$\sum_{feed} I\gamma$	$\sum_{decay} I\gamma$	$\sum_{decay} I\gamma$-$\sum_{feed} I\gamma$	B.R% (present work)
82.20	4037.8	234.2	34	—	—
271.98	3848.02	140.59	131	—	—
564.88	3555.12	8.0	9.9	1.9	0.674739
1088.27	3031.73	18.6	19.1	0.5	0.177563
1132.14	1987.86	17.4	20.4	3	1.065378
1193.47	2926.53	13.85	16.1	2.25	0.799034
1260.97	2859.03	0.3	15	14.7	5.220355
1283.6	2836.4	1.10	4.3	3.2	1.136403
1341.82	2778.78	52.22	118	65.78	23.360204
1431.82	2688.18	33.8	38.3	4.5	1.598068
1435.5	2684.5	—	5	5	2.287387
1498.78	2621.22	5.78	6.15	0.37	0.1313967
1575.61	2544.39	2.4	11.7	9.3	3.30267
1630.26	2489.74	2.5	9.03	6.53	2.318974
1671.56	2448.44	80.6	67.6	—	—
1798.30	2321.7	8.7	7.7	—	—
2053.49	2066.51	10.4	88.78	78.38	27.83479
2153.6	1966.4	—	10.7	10.7	3.7998508
2295.4	1824.6	—	3.0	3.0	1.065378
2480.9	1639.1	1.9	5.3	3.4	1.207429
2537.9	1582.1	—	4.0	4.0	1.420504
2949.9	1170.1	—	9.1	9.1	3.231648
2954.0	1166	—	25.1	25.1	8.9136688
3052.4	1067.6	—	9.26	9.26	3.288469
3186.5	933.5	—	21.62	21.62	7.677829

Table (2) The Log ft values assignment for $^{176}_{70}Yb$ Isotope Levels

Energy Level (KeV)	ΔLog ft	Log f_0t	Log c	Log ft	
				Present work	Ref. [13]
82.20	——	——	——	——	——
271.98	——	——	——	——	——
564.88	2.17	5.2	1	8.37	——
1088.27	2.75	4.8	1.05	8.6	——
1132.14	1.97	4.73	1.06	7.76	——
1193.47	2.09	4.7	1.06	7.85	——
1260.97	1.28	4.65	1.07	7.0	——
1283.6	1.94	4.6	1.08	7.62	——
1341.82	0.63	4.5	1.1	6.23	6.25
1431.82	1.79	4.351	1.12	7.261	——
1435.5	1.64	4.350	1.13	7.12	——
1498.78	2.88	4.34	1.14	8.36	——
1575.61	1.48	4.32	1.145	6.945	——
1630.26	1.63	4.3	1.15	7.08	——
1671.56	——	——	——	——	——
1798.30	——	——	——	——	——
2053.49	0.56	4.0	1.16	5.72	5.65
2153.6	1.42	3.9	1.17	6.49	6.44
2295.4	1.97	3.8	1.18	6.68	6.87
2480.9	1.92	3.6	1.2	6.72	6.62
2537.9	1.85	3.5	1.21	6.56	6.49
2949.9	1.49	3.05	1.22	5.76	5.66
2954.0	1.05	3.0	1.22	5.27	5.21
3052.4	1.48	2.75	1.23	5.46	5.50
3186.5	1.11	2.6	1.25	4.96	4.92

4. Results and Discussion:

The present studies on the levels have clarified numerous cases of conflicting data that existed previously. Further, the present measurements have establish the properties of the excited states in this nucleus. Several excited states were established before and further confirmed in this work. In this present, some levels were discussed as example for the other levels.

Levels (82.20 , 271.98, 1671.56, 1798.30) KeV

In this present work does not determine the (Log ft), of these levels because the gamma rays feeding them greater than the gamma rays decaying , therefore we can't determine branching ratio As a result the other calculations such as ($Logc$,$Logf_0t$, $\Delta Logft$) negligible.

Levels (564.88, 1088.27, 1132.14, 1193.47, 1260.97, 1283.6, 7.261, 7.12, 8.36, 6.945, 7.08) KeV

These levels deserve some attention as there appear to be ambiguity about the (Log ft) assignment. The decay study [13] does not determine the (Log ft), of these levels. The present work limited it for the first time.These words applying to other levels. . .

Levels (1341.82, 5.72, 6.49, 6.68, 6.72, 6.56, 5.76, 5.27, 5.46, 4.96) KeV

In these levels there's agree about the (Log ft) assignment. The decay study [13] determined the ($Log\ ft$) for these levels by (6.25, 5.72, 6.49, 6.68, 6.72, 6.56, 5.76, 5.27, 5.46, 4.96), and in present work by (6.23, 5.65, 6.44, 6.87, 6.62, 6.49, 5.66, 5.50, 4.92) respectively, this an indicator in good corresponding with results.

5. Conclusions

1- The value of ($Log\ ft$) depends on the branching ratio (B.R%), which in turn depends mainly on the beta transitions, feeder and dissolved ($\sum_{feed} I\gamma$,$\sum_{decay} I\gamma$).
2- The present work limited ($Log\ ft$) of some levels for the first time, this means it can be used as a source in future studies.
3- Some of levels agree about the (Log ft) with corresponding results , this confirms the validity of the present work.

6. Reference

[1] N. Hinkley, J.A. Sherman, N.B. Phillips, M. Schioppo, N.D. Lemke, K. Beloy, M. Pizzocaro, C.W. Oates, A.D. Ludlow. An atomic clock with 10-18 instability. Science Express,(2013).

[2] Universal Nuclide Chart. Nucleonica, (2011).

[3] Konya, J.; Nagy, N. M. (2012). Nuclear and Radiochemistry. Elsevier. pp. 74–75.

[4] Jean – Louis Basdevant, James Rich, Michel Spiro, Fundamentals in Nuclear Physics. Springer, (2005).

[5] Moszkowski S. A. ,Physics Rev., Vol. 82, No.1, 35, (1951).

[6] Loveland, Walter D. (2005). Modern Nuclear Chemistry. Wiley. p. 232.

[7] R.D. Salman: M.Sc. Thesis, Al-Mustansiriyah University (1992).

[8] Konopinski, E.J., Rev. Mod. Physics 15, p.209, (1943).

[9] Leder H. and Perlman , Table of Isotopes , Sixth Edition, (1967).

[10] G. M. Lederer and V. S. shirly, Table of Isotopes, Wiley (1978).

[11] B. Pandey, H. M. Agrawal, R. Pepelnik, Applied Radiation and Isotopes, Vol.85, p.128,(2014).

[12] Ameer A. A. ,Ph.D. Thesis, Bedford College, University of London, (1991).

[13] M.S.Basunia, Nuclear Data Sheets for A=176, Lawrence Berkeley National Laboratory., Vol.107, p.791 (2006).

[14] A.M.Hurst, Nuclear Data Sheets for A=176, Vol.119, p.91,(2015).