Multipole Mixing Ratios for Gamma transitions in ^{56}Fe populated in ^{56}Fe (n,nγ)^{56}Fe Reaction by using least square fitting method .

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Abstract

The γ- mixing ratios of γ- transitions from levels of ^{56}Fe populated in ^{56}Fe (n,nγ)^{56}Fe reaction are calculated using least square fitting program for the first time in the case of pure and mixed transitions the results obtained have been compound with γ

Values determined by other methods .The comparison shows that the agreement is good this confirmed the valilety of this method in calculating of values for such γ- transitions key word: γ- transition ,Multipole mixing ratios ,Least square fitting method.

Introduction

The energy levels of ^{56}Fe have been studied by AL-jeboori et al.[1] using (n, n$'$γ) reaction with reactor 14 MeV incident neutron . Excited states up to 5.3 Me V were populated and 47 gamma rays de-exciting 26 energy levels observed. Angular distributions of γ-rays with respect to the neutron beam have been measured. Spin assignment previously established for 18 levels have been confirmed. Ambiguities involving the 4119.8 and 4457.8 keV have been resolved revealing spin-parity assignments of 3^+ and 4^+ respectively. Gamma ray branching ratio's have been determined and compared with previons results. The mixing ratios for several gamma transitions have been deduced and compared with those provost reported by other authors.

Mack Donald and Grace[3], have studied the energy levels of ^{56}Fe using (p, p γ) reactions. Hofman [4] have studied the energy levels of ^{56}Fe by λ-γ directional correlation following the decay of ^{56}C and ^{56}Mn. Bened joballah et al. [5] have studied the nuclear structure of ^{56}Fe by ^{50}Cr (^{12}C , α_2 p γ) ^{56}Fe, ^{56}Fe (α, α γ) ^{56}Fe and the spin and multipole mixing rations for these levels were measured.

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Data Reduction and analysis

Levels with certain (j_i) values might have no pure γ-transition or transition considered to be pure. The statistical tensor $\rho_2(j_i)$ for such levels cannot be calculated and hence the δ-values of mixed transition from such levels cannot be determined by the CST-Method.

It also happens that a level with certain j_i - values has only one pure γ-transition or considered to be pure γ-transition whose a_2-coefficieut is not accurately measured in which case, the statistical tensor $\rho_2(j_i)$ calculated for that level shall be inaccurate also.

The LSF method was there for, suggested to estimate $\rho_2(j_i)$ for all j_i -values.

The $\rho_2(j_i)$ values calculated for level with different j_i -values, were computer fitted to a polynomial series of the form :

$$\rho_2(j_i) = \sum_{i=o}^{i=n} \mathrm{A_i} J_i^{\pi}$$

In this Method, the $\rho_2(j_i)$ values calculated for levels with different j_i values are computer fitted to a polynomial series of the form:

$$\rho_2(j_i) = \sum_{x=o}^{x=n} \mathrm{B_x} J_i^{*} \text{ ....(1)}$$

With n=1,2,3.4 and 5, using the least square fitting program that was written in the present work in matlab language to determine the $\mathrm{B_x}$ parameters for all n-values and the R^2-values for each n which represent the minimum difference in experimental and theoretical values of $\rho2(j_i)$values.

The set with best R^2 was then used to calculate the $\rho_2(j_i)$ values for all j_i values . The $\rho_2(j_i)$ values thus obtained are then used to calculate the δ-values for all γ-transition whose angular distribution have been measured.

Results and Discussion

The weighted averages of $\rho_2(j_i)$ presented in table (1) were computer fitted as mentioned.

The fitting equation was as follows:

$$\rho_2(j_i) = 0.99204 - 1.7394\ j_i + 0.7042\ j_i^2$$

$$- 0.13113\ j_i^3 + 0.008742\ j_i^4 + \ldots\ldots\ldots\ldots(2)$$

The $\rho_2(J_i)$ values calculated for each J_i were then as follows:

$\rho_2(1) = -0.165$
$\rho_2(2) = -0.577$
$\rho_2(3) = -0.710$
$\rho_2(4) = -0.819$
$\rho_2(5) = -0.945$
$\rho_2(6) = -0.917$

The statistical $\rho_k(J_i, M_i)$ are also constant for j_i values.

The according to:

$$\rho_{k(J_i)} = \sum \rho_k(j_i, M_i)\rho(mi)$$

The statistical tensor $\rho_k(J_i)$ would also be constant for level with the same (J_i) value so eq. (3) can be used to calculate multipole mixing ration for γ-transition for each levels where (J_i) is constant by using $\rho_k(J_i)$ values as follows:

$$a_2(J_i - J_F) = \rho_2(J_i)F_2(J_i J_F \delta)\ldots\ldots\ldots\ldots(3)[6]$$

Where $F_2(J_iJ_F\delta)$ is parameters included information about angular momentum and mixing ratio and given by:

$$F_2(J_iJ_F\delta)=\frac{F_2(J_FL_1L_1J_i)+2\delta F_2(J_FL_1L_2J_i)+\delta^2F_2(J_FL_2L_2J_i)}{(1+\delta^2)}\text{..........(4)[7]}$$

Where the F$_2$ values weve reprented in Appendix[I] :

$$L_1=\left|J_i-J_F\right|\neq 0\text{...........(5)}$$

$$L_2=L_1+1\text{.....................(6)}$$

Sub-eq(4) in eq(3) the result as follows:

$$a_2(J_i-J_f)=\rho_2(J_i)\frac{F_2(J_FL_1L_1J_i)+2\delta F_2(J_FL_1L_2J_i)+\delta^2F_2(J_FL_2L_2J_i)}{1+\delta^2}\text{......(7)}$$

$$a_2(\overset{+}{2}-\overset{+}{2})=\rho_2(2)\frac{-0.41833-1.22476\delta+0.12806\delta^2}{(1+\delta^2)}\text{......(8)}$$

$$a_2(\overset{+}{3}-\overset{+}{2})=\rho_2(3)\frac{+0.34641-1.89738\delta-0.12372\delta^2}{(1+\delta^2)}\text{......(9)}$$

$$a_2(\overset{+}{3}-\overset{+}{4})=\rho_2(3)\frac{+0.14434+1.44338\delta+0.309298\delta^2}{(1+\delta^2)}\text{......(10)}$$

$$a_2(\overset{+}{4}-\overset{+}{2})=\rho_2(4)\frac{-0.44770-1.05944\delta-0.47009\delta^2}{(1+\delta^2)}\text{......(11)}$$

$$a_2(\overset{+}{4}-\overset{+}{4})=\rho_2(4)\frac{-0.43875-0.67082\delta+0.26455\delta^2}{(1+\delta^2)}\text{......(12)}$$

$$a_2(\overset{+}{6}-\overset{+}{4})=\rho_2(6)\frac{-0.40291-1.13960\delta-0.502198\delta^2}{(1+\delta^2)}\text{......(13)}$$

$$a_2(\overset{+}{6}-\overset{+}{6})=\rho_2(6)\frac{-0.44320-0.46292\delta+0.29355\delta^2}{(1+\delta^2)}\text{......(14)}$$

The δ-values calculated using these $\rho_2(J_i)$ values are presented in table (1). The comparison of δ-values calculated by this method with those calculated by reference [1][2] shows that the agreement is excellent for γ-transition from levels with J_i =1,2,3,4,5 within

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associated errors, the discrepancy occurs in the case of 2425.5 keV (3^+- 4^+) transition from 4510.4 keV level.

This indicates that the inaccuracy of the a_2-cofficient reported in reference [1] for this transition.

Conclusion

The δ-values of γ-transitions from levels in ^{56}Fe populated in ^{56}F (n,nγ)^{56}F$'$ reaction have been calculated in the present work using LSF-Method and the statistical tensors $\rho_2(J_i)$ reported in reference [2]. The good agreement between the δ-values calculated by this method for most γ-transitions confirm the validity of this- method for calculating the δ-values of γ-transitions, also this method depends upon the experimental data[1] only and a personal computer can be used to perform all the necessary calculations.

Table (1)

Multipole Mixing Ratios for γ- transitions from levels in ^{56}Fe (n,n $'\gamma$)

in case of pure transitions CST(1) and Mixed transitions CST and LSF method

E_i(KeV)	E_γ(KeV)	J_i -J_f	$\frac{a_2}{a_4}$[1]	δ [1]	δ values		
					CST (2)	CST (1)	$LSF\ p.w$
846.7	846.7	2^+-0^+	0.304(16) -0.068(18)	E2	E2	E2	E2
2084.9	1238.2	4^+-2^+	0.311(32) -0.100(40)	-0.04(4)	-0.06(4)	0.01(5)	-0.06(4) $-(11.66\ ^{+8.97}_{-3.58})$
2941.6	2094.9	0^+-2^+	-0.04(4) -0.09(5)	E2	E2	E2	E2
2959.6	2112.9	2^+-2^+	0.270(24) -0.068(29)	0.05(4) 2.0(2)	0.04(4) 2.0(2)	0.09(5) 1.8(2)	0.04(4) 2.0(2)
3122.8	2276.0	4^+-2^+	0.298(15) -0.081(19)	-0.08(2)	-0.08(2)	0.00(2)	-0.08(2) $-(9.9\ ^{+2.1}_{-1.5})$
	1037.9	4^+-4^+	0.267(14) -0.064(17)	-0.15(2) 1.30(6)	-0.15(2) 1.3(1)	-0.06(3) 1.1(1)	-0.15(2) $(1.3\ ^{+0.04}_{-0.1})$
3369.7	2523.0	2^+-2^+	0.361(39) 0.010(47)	0.19(8) 1.5(2)	$(0.19\ ^{+0.09}_{-0.07})$ 1.4(3)	$(0.29\ ^{+0.17}_{-0.10})$ 1.2(3)	$(0.19\ ^{+0.09}_{-0.07})$

							$(1.4^{+0.3}_{-0.2})$
3388.1	1303.2	6^+-4^+	0.364(64) -0.012(75)	-0.02(7)	-0.01(7)	-0.01(7)	$-(0.01^{+0.06}_{-0.07})$ $(12.03^{+33.67}_{-5.33})$
3445.4	2598.5	3^+-2^+	-0.428(25) -0.020(32)	-0.15(2)	-0.14(3) -2.5(2)	-0.08(5) -3.0(4)	-0.14(2) $-(2.5^{+0.1}_{-0.2})$
	1360.2	3^+-4^+	0.113(38) -0.037(44)	-0.23(5) -2.9(5)	-0.23(5) -2.9(4)	-0.20(4) -3.1(4)	$-(0.23^{+0.04}_{-0.05})$
3445.4	2598.4	1^+-0^+	0.113(38) -0.037(44)	M1	M1	M1	M1
3601.6	3601.6	2^+-0^+	0.373(83) -0.048(100)	E2	E2	E2	E2
3755.9	1670.8	6^+-4^+	0.389(68) -0.024(84)	0.03(8)	0.02(8)	0.02(8)	0.02(7) $(9.3^{+14.6}_{-3.6})$
	368.0	6^+-6^+	0.362(83) -0.058(98)	-0.08(17)	$-(0.09^{+0.15}_{-0.23})$ $(0.76^{+0.27}_{-0.33})$	$-(0.09^{+0.16}_{-0.24})$ $(0.76^{+0.28}_{-0.34})$	$-(0.09^{+0.14}_{-0.2})$ $(0.76^{+0.24}_{-0.28})$
4048.4	3201.3	3^+-2^+	0.444(44) 0.040(73)	0.59(9)	0.61(8) 3.2(6)	0.51(4) $(4.3^{+0.8}_{-0.6})$	$(0.6^{+0.1}_{-0.4})$ $(3.2^{+0.4}_{-0.02})$
	1089.1	3^+-2^+	0.271(104) -0.1216(130)	0.40(10)	0.4(11) (7^{+11}_{-3})	$(0.36^{+0.09}_{-0.07})$ $(9.5^{+15.9}_{-3.9})$	0.4(1) (7^{+10}_{-3})
4099.7	3252.9	3^+-2^+	0.205(166) -0.178(205)	0.34(14)	0.35(15)	$(0.31^{+0.14}_{-0.11})$	$(0.34^{+0.16}_{-28.14})$
4119.4	2034.8	3^+-4^+	-0.128(21) 0.023(26)	0.02(2)	0.02(2) $-(11.2^{+3.4}_{-2.2})$	0.00(2) $-(9.0^{+2.4}_{-1.5})$	0.02(2) $-(11.2^{+3.4}_{-2.2})$
4401.2	3554.1	3^+-2^+	-0.264(89) 0.0	-0.01(7)	-0.02(7) $-(3.8^{+1.3}_{-0.9})$	0.02(6) $-(4.4^{+1.6}_{-1.0})$	$-(0.01^{+0.07}_{-0.06})$ $-(3.8^{+1.4}_{-0.8})$
4457.2	1335.0	4^+-4^+	0.420(151) -0.187(182)	$(0.15^{+?}_{-0.29})$ $(0.70^{+0.58}_{-?})$	$(0.13^{+?}_{-0.28})$ $(0.73^{+0.55}_{-?})$	جذور خيالية	$(0.13^{+?}_{-0.27})$ $(0.7^{+0.5}_{-?})$
4510.4	2425.5	3^+-4^+	-0.372(125) 0.056(125)	-0.08(6) -3.0(8)	$(0.27^{+0.17}_{-0.13})$ $(6.5^{+32.5}_{-3.3})$	$(0.20^{+0.13}_{-0.11})$	$(0.27^{+0.17}_{-0.13})$ $(6.5^{+30.8}_{-3.2})$
	1852.8	3^+-2^+	-0.475(178) 0.405(212)	$-(0.16^{+0.18}_{-0.13})$ $-(2.4^{+1.3}_{-0.8})$	$-(0.18^{+0.20}_{-0.14})$ $-(2.2^{+1.3}_{-0.8})$	$-(0.11^{+0.17}_{-0.12})$ $-(2.7^{+1.3}_{-0.9})$	$-(0.18^{+0.2}_{-0.14})$ $-(2.2^{+1.3}_{-0.8})$

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Appendix I

J_i	L	L	J_f	F_2	F_4
1.0	1.0	1.0	0.0	0.70711	0.00000
1.0	1.0	1.0	1.0	-0.35355	0.00000
1.0	1.0	2.0	1.0	-1.06067	0.00000
1.0	2.0	2.0	1.0	-0.35355	0.00000
1.0	1.0	1.0	2.0	0.07071	0.00000
1.0	1.0	2.0	2.0	0.47434	0.00000
1.0	2.0	2.0	2.0	0.35355	0.00000
1.0	2.0	2.0	3.0	-0.10101	0.00000
1.0	2.0	3.0	3.0	0.37796	0.00000
1.0	3.0	3.0	3.0	0.53034	0.00000
1.0	3.0	3.0	4.0	-0.17678	0.00000
2.0	2.0	2.0	0.0	-0.59761	-1.06904
2.0	1.0	1.0	1.0	0.41833	0.00000
2.0	1.0	2.0	1.0	-0.93542	0.00000
2.0	2.0	2.0	1.0	-0.29881	0.71269
2.0	1.0	1.0	2.0	-0.41833	0.00000
2.0	1.0	2.0	2.0	-0.61238	0.00000
2.0	2.0	2.0	2.0	0.12806	-0.30544
2.0	1.0	1.0	3.0	0.11952	0.00000

2.0	1.0	2.0	3.0	0.65466	0.00000
2.0	2.0	2.0	3.0	0.34149	0.07636
2.0	2.0	2.0	4.0	-0.17075	-0.00848
2.0	2.0	3.0	4.0	0.50507	-0.06274
2.0	3.0	3.0	4.0	0.44822	-0.02970
2.0	3.0	3.0	5.0	-0.29881	0.00405
3.0	3.0	3.0	0.0	-0.86603	0.21320
3.0	2.0	2.0	1.0	-0.49487	-0.44670
3.0	2.0	3.0	1.0	-0.46290	1.04463
3.0	3.0	3.0	1.0	-0.64953	0.03553
3.0	1.0	1.0	2.0	0.34641	0.00000
3.0	1.0	2.0	2.0	-0.94869	0.00000
3.0	2.0	2.0	2.0	-0.12372	0.67006
3.0	1.0	1.0	3.0	-0.43301	0.00000
3.0	1.0	2.0	3.0	-0.43301	0.00000
3.0	2.0	2.0	3.0	0.22682	-0.44670
3.0	1.0	1.0	4.0	0.14434	0.00000
3.0	1.0	2.0	4.0	0.72169	0.00000
3.0	2.0	2.0	4.0	0.30929	0.14890
3.0	2.0	2.0	5.0	-0.20620	-0.02030
3.0	2.0	3.0	5.0	0.54554	-0.13430
3.0	3.0	3.0	5.0	0.36085	-0.05492

3.0	3.0	3.0	6.0	-0.36085	0.00969
4.0	3.0	3.0	1.0	-0.78349	0.14527
4.0	2.0	2.0	2.0	-0.44770	-0.30438
4.0	2.0	3.0	2.0	-0.52972	0.90036
4.0	3.0	3.0	2.0	-0.47009	-0.04842
4.0	1.0	1.0	3.0	0.31339	0.00000
4.0	1.0	2.0	3.0	-0.94018	0.00000
4.0	2.0	2.0	3.0	-0.04477	0.60876
4.0	1.0	1.0	4.0	-0.43875	0.00000
4.0	1.0	2.0	4.0	-0.33541	0.00000
4.0	2.0	2.0	4.0	0.26455	-0.49807
4.0	1.0	1.0	5.0	0.15955	0.00000
4.0	1.0	2.0	5.0	0.75679	0.00000
4.0	2.0	2.0	5.0	0.28490	0.19370
4.0	2.0	2.0	6.0	-0.22792	-0.02980
4.0	2.0	3.0	6.0	0.56407	-0.18437
4.0	3.0	3.0	6.0	0.29915	-0.06874
4.0	3.0	3.0	7.0	-0.39887	0.01422
5.0	3.0	3.0	2.0	-0.73599	0.11589
5.0	2.0	2.0	3.0	-0.42056	-0.24281
5.0	2.0	3.0	3.0	-0.55634	0.80301
5.0	3.0	3.0	3.0	-0.36799	-0.07726

5.0	1.0	1.0	4.0	0.29439	0.00000
5.0	1.0	2.0	4.0	-0.93095	0.00000
5.0	2.0	2.0	4.0	0.00000	0.56556
5.0	1.0	1.0	5.0	-0.44159	0.00000
5.0	1.0	2.0	5.0	-0.27386	0.00000
5.0	2.0	2.0	5.0	0.28307	-0.52297
5.0	1.0	1.0	6.0	0.16984	0.00000
5.0	1.0	2.0	6.0	0.77832	0.00000
5.0	2.0	2.0	6.0	0.26689	0.22413
5.0	2.0	2.0	7.0	-0.24263	-0.03736
5.0	2.0	3.0	7.0	0.57416	-0.22100
5.0	3.0	3.0	7.0	0.25476	-0.07726
5.0	3.0	3.0	8.0	-0.42461	0.01783
6.0	3.0	3.0	3.0	-0.70510	0.09967
6.0	2.0	2.0	4.0	-0.40291	-0.20883
6.0	2.0	3.0	4.0	-0.56980	0.73833
6.0	3.0	3.0	4.0	-0.30219	-0.09018
6.0	1.0	1.0	5.0	0.28204	0.00000
6.0	1.0	2.0	5.0	-0.92319	0.00000
6.0	2.0	2.0	5.0	0.02878	0.53699
6.0	1.0	1.0	6.0	-0.44320	0.00000
6.0	1.0	2.0	6.0	-0.23146	0.00000
6.0	2.0	2.0	6.0	0.29355	-0.53699

6.0	1.0	1.0	7.0	0.17728	0.00000
6.0	1.0	2.0	7.0	0.79283	0.00000
6.0	2.0	2.0	7.0	0.25326	0.24613
6.0	2.0	2.0	8.0	-0.25326	-0.04343
6.0	2.0	3.0	8.0	0.58028	-0.24879
6.0	3.0	3.0	8.0	0.22160	-0.08292
6.0	3.0	3.0	9.0	-0.44321	0.02073

نسب الخلط لأشعة كاما المنبعثة ^{56}Fe من تفاعل ^{56}Fe (n,nγ)^{56}Fe بطريقة تطابق المربعات الدنيا

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الخلاصة

حسبت نسب الاختلاط (γ) لانتقالات كامية منبعثة عن مستويات ^{56}Fe متولدة من التفاعل ^{56}Fe (n,nγ)^{56}Fe باستخدام طريقة مطابقة المربعات لدينا والتي استخدمت لأول مرة في حالة الانتقالات المختلطة والنقية وقد تم مقارنة النتائج التي تم الحصول عليها مع قيم γ المقاسة بطرق أخرى وقد وجد إن الاتفاق كان جيد , وهذا يثبت إن الطريقة الحالية قد استخدمت بنجاح في حساب قيم γ لمثل هذه الانتقالات .

كلمات مفتاحية: انتقالات أشعة كاما , نسب الخلط , طريقة مطابقة المربعات الدنيا.