Collective Excitation of Kr-82

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Abstract

The energy level scheme of ^{82} Kr has been established on the basis o singles gamma spectra, gamma coincidence and compton suppressio measurements. Ge(Li) detectors were used to study the gamma spect produced in the β - decay of ^{82} Br to ^{82} Kr.

A total of thirty-six γ -rays were observed, of which two, at 182.9 and 454.98 kev are new. These two transitions are considered t depopulate new (5$^-$) level at 3001-31 keV . Relative intensities and lo ft values were calculated and spin / parities deduced .

Introduction

The β -decay of Br (t=35.3h, J* =5-) to Kr presents the opportuni to study the levels of an even –even nucleus in a rather unique manne Since the ground state of Br has a spin and parity 5 (Artna[1]), the β decay proceeds entirely to high spin negative parity levels situated 2648.37 and 2828.14 KeV above the ground state of ^{82}Kr. Such leve are not often populated in β-decay, and consequently, the informatio about them is rather meager. In addition, these high spin states mu decay by successive γ -transitions through states of lower spin to th ground states O^+ of^{82} Kr. Since the yield of γ - γ coincidence high, a large amount of information concerning the level structur of^{82}Kr can be found by studying the decay of ^{82}Br. The study of th decay of ^{28}Br . has been undertaken by a number of previous author (2-3) . The nucleus of ^{82} Kr is also unique in that the levels can b populated by founr different precursors which have a variety of spins Consequently, ^{82}Kr. has also been studied of ^{82} Rb has identified one o more O^+ state, in ^{82}Kr, which has not been observed in the decay of^{82}Br.In addition,higher spin lenvels can be reached by the ^{82}Se

(α ,2nγ) reaction and heavy ion reaction (4-5). The study of kiang et al (6) has provided lifetime measurements for the 777,1475 1821, and 2094 KeV levels in ^{82} Kr and the value of B(E2:$2_1^+ \longrightarrow 0_1^+$) for the transition to the lowest excited states . The ^{82} Se(α ,2n) reaction studies of Meyer et al (4) and Kemnitz et al (5) have provided additional experimental evidence for the existence of many of the levels in ^{82} Kr, as well as identifying several additional levels. The latest ^{82} Br decay measurements by Meyer et al (4) , using a compton suppression system with an 8cm (3)Ge(Li) detector, showed the existence of new transitions at 734.1 and 1099.9 KeV, but not those at 280.7, 470.25, 625.50 , 692.70, 726.8, 353.20 and 1426.0 KeV. The latter list of transitions had been observed by Meredith and Meyer (4) using the same system, but the former were not . The relative intensities reported by Meyer et al (4) differ in a few cases from Sooch etal (8) by more than the combined uncertainties. The spins and parities of the first few excited states and multipole admixtures in many gamma transitions of ^{82} Kr have been determined from γ-γ directional correlation measurements. Many of these experiments employed Nal (Tl)- NaI (Tl) detector combinations. Gardulski and Wiedenbeck (9) used the NaI (Tl)-Ge(Li) and Ge (Li)-Ge(Li) detector combinations but their results gave insufficient details. In particular, there appears to be some ambiguity about the spin/parity assignment of levels at 2427,2547 and 2556 KeV. The 2427 KeV level wsa suggested to be either spin 3 or 4 by Hsu and Wu(10) , was assigned spin 3 based on the directional correlation measurements of Guptat and Bajaj (11) , indicated as a 3^- octupole state by Liukkonen etal (12), but given as 4 by Meyer etal (4). The 2547 KeV level was suggested to have $J^*=3^+$ by Meyer et al (4), while results of Kemnitz et al (5) favoured 3^-.

The level at 2556 KeV was given as 3^- by Meyer etal (4) , but work of Kemnitz et al (5) and Brussermaan et al (13) suggested the spin parity to be 4^+. The results of Kiang et al (3) seem to have an unusual energy calibration and are mainly of interest for their IBM-2 calculation .

Keeping in view the above mentioned inconsistencies and discrepancies, it was thought worthwile to reinvestigate the decay scheme of ^{82} Kr, in order to provide a more complete understanding of the low energy excitations . This was accomplished using the Ge(Li) , intrinsic Ge detector and the Compton suppression system for energy and intensity measurement of various gamma transitions and a Ge (Li)

–Ge(Li) detector combination in fast slow cioncidence mode f cioncidence measurements . In this work, one new energy level a two and possible new transitions have been placed in the decay schem . These were confirmed from the cioncidence data and energy su relations.

Experimental procedure and results

Source preparation: The ^{82} Br source was produce by thermal neutron capture (n, γ) irradiation of 20 mg of natural bromine (in th form of NH_4Br) in the ICRC. The resulting radioisotope of ^{82}B ($t_{1/2}$=35.3h) of roughly 30 μCi of activity was placed in a standar polythene capsule and was kept for two days before taking an measurements . This allowed for the 4.5h ^{80m}Br activity to decay .

Singles measurements:- For the gamma ray energy and intensit measurement of ^{82} Br, four spectra form the 10% efficient Ge (Li detector were measured using four soures made at different times Also, one spectrum form the Compton suppression system and on from the HPGe detector (spanning the region 50-350 KeV) wer collected and analysed (see table (1) for the specifications of thes detectors). The source was plased at 25 cm from the detector to avoi summing effects. One of the singles spectra of the Ge (Li) detector wa taken with a 2cm Pb absorber placed in front of the detector surface The Pb absorber was used to suppress intensive low energy gamma ra which are sources of sum peaks. The spectra were collected via a Ortec ACE card plugged into an PC computer. The data for efficiency calibration were analysed. Fig.(1) shows a typical gamma ray singl spectrum following the β -decay of ^{82}Br. Fig. (2) illustrates the γ spectrum from the decay of ^{82}Br as measured with the compto suppression system which proved to be very useful for the detection o low energy γ - rays lying on a large compton background. The energy calibration of the detector was done using the intense gamma rays of accurately known energies 92.19, 221.48, 554.34, 776.52, 1044.06, 1317.45, and 1650.37 KeV. The computer code SAMPO 80 was used for data anlysis . The singre spectrum was corrected for the background. The energies and relative intensities of all transitions observed in the present work are listed in table (1) together with relative intensities reported by other workers (8-4).

For the final results a weighted average was taken . Among the thirty seven transitions of this table , two at 182.97 and 454.98 KeV were observed for the fitst time . The 345.6 and 932.1 KeV γ -ray shown Meredith Meyer and (7) (also by Meyer et al 4) as well as those at 836.70 and 1426.0 KeV (also reported by Sooch et al 8) were not present in any of the spectra .

Coincidence measurement : γ - γ coincidence measurement s were done by using thec10% and 9.6% efficient Ge(L0\i) detector placed at 90 relative to each other in ordre to suppress detector to detector backscattering effect . Five coincidence spectra gated at 698, 777,1044,1317, and 1475 KeV were taken . The first excited state in the ^{82} Kr nucleus is at 777 KeV .Thus, we expect most of the transitions from higher states will either be populated directly or cascade in with this level . Hence , the 777 KeV gate is very important in constructing the lvel scheme of this nucleus. Source to detector distance was 10 cm and 15 cm from the 9.6% and 10% detectors , respectively . The coincidence spectrum for the one gates is shown in fig.(3).

Decay Scheme : The decay schems of the ^{82} Kr nucleus established from the results of coincidence and energy sum relations, is shownin fig.(4) The level energy (KeV) , branching ratios, log ft values , spins and parities are given on the left side of the figure. The number at the base of the arrow indicates the energy of the transitions in KeV . The new transitions and levels are shown as dashedlines . Table (2) shows the branching ratios (B.R's), the log ft values for the β-decay of ^{82} and deduced spins and parities . The B.R s were computed from the total intensity balanced between the decay and feeding γ - rays for each level. The log ft values were calculated according to the β-decay the were calculated using the given Qβ value (15) of 3092.5 KeV for ^{82} Br. The spin /parities were deduced according to the β- decay selection rules . The results for B.R's and log ft values obtained in the present work were comparable to that compiled by (Nucl. Data sheets 15). Table (3) shows the comparisons of experimental and theoretical K shell conversion coefficients (α_k) for the γ - ray transitions from the β-decay of ^{82} Br . The experimental α_k values were computed using $\alpha_k = N_{ek}/ N$. The β electron intensities were taken from the work of Waddell and Jensen (16) while the relative intensities of the γ

- transitions were taken from singles measurements reported in table(1) The multipolarity for some of the transitions was deduced by comparing the experimental α_k value obtained with the theoretical α_k value(17) . The multipolarities adopted for the transitions are given in the last colmn of table (3).

The newly observed level at 3011.31 KeV is suggested by observation of two new transitions at 183.97 KeV and 455.98 KeV which depopulate to the levels at 2828.14 and 2556.39 KeV respectively . These transitions are sen in all the measurements done by Ge(Li), Ge detector and Compton suppression system . Both transitions are also observed in the coincidence spectra with gatres energies at 1044 and 698 KeV, respectively . The log ft a grees with the results of Rb(5) decay and in beam reaction.

Discussioin

Extensive γ - ray singles and coincidence measurements have enabled a comprehensive decay schems for ^{82}Kr nucleus to be built up following the 35.3hradioactive decay of ^{82} Br . Two new transitions at 182.87 and 454.98 KeV and one energy level (5$^-$)at 3011.31 KeV have been placed in the decay scheme. The observed spectra rule out the existence of transitions reported by Meredith and Meyer (7) at 346 and 932 KeV (also by Meyer et al (4)) as well as those at 836 and 1427 KeV (also reported by Sooch et al (8)) . The present work removed early ambiguities and allowed an accurate spin / parity assignment for the level at 2426.90 , 2547.36 and 2556.39 KeV .

Since the first excited state of ^{82} Kr lies fairly high in energy 776.53 KeV , the deformation of this nucleus is probably small. This suggests that the excited levels may be due to quadrupole phonon vibrations of the nucleucs surface . Within this interpretation , the first excited state at 776.53 KeV (2^+) would correspond to the one phonon singlet state. The next,excited state at 1474.90 KeV spin and parity 2^- and thus, could be the 2^+ member of the two phonon triplet . This state de populates through transitions to the first 2^+ state and the O^+ ground state . The 4^+ state at 1820.59 KeV could be the 4^+ member of the two phonon triplet.It is interesting that this state lies considerably higher in energy than the 1474.90 KeV (2^+) level. This contrasts with ^{7},Se where the separation is only ~ 115 KeV. The O^+member of the triplet does not appear to be populated by ^{82}Br (5-) decday, however, it might

be expected that this state would be populated in ^{82} Rb(1^+) decay. The existence of O^+ state at 2171.8 KeV has been confirmed by the directional correlation study of Hrynkiewicz et al (18), but this state is probably too high in energy to be a member of the triplet states and it is more likely one of the quintet state . A more likely candidate for the O^+ two phonon state is the level at 1487 KeV , which was also observed by Hrynkiewicz et al (18) in the decay of ^{82} Rb. The spin and parity of this level has not been confirmed by directional correlation measurements, but since it dose not decay to the ground state, it may have $J^*=O^+$ .The levels at 2093.93 KeV 3^+ and 2426.90 KeV (4^+) which are populated in ^{82} Br decay, could be members of three phonon quintet. The γ - transitions from these levels to members of the triplet appear to be enhanced over the transitions to the singlet state.

The γ- member of the quintet could be the level at 1956.79 KeV, however, this interpretion is weak, since the spin and parity of this level have not been definitely assigned . Futhermore , it is populated by decay of the 2093.93 KeV level (3^+) and it does not appear to decay to the triplet states.

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Table (1) Relative intensities of γ - rays emitted from the decay of ^{82}Br.

Energy (keV)	Intensity related to $I_\gamma(776)=100$		
	Present work	Meyer *et al* [78]	Sooch *et al* [77]
92.190 (018)	0.895 (013)	0.90 (03)	0.86 (03)
100.94 (07)	0.082 (008)	0.084 (008)	0.073 (005)
129.60 (16)	0.017 (007)	0.036 (007)	0.025 (005)
137.22 (03)	0.156 (007)	0.182 (002)	0.13 (01)
179.51 (20)	0.035 (007)	0.012 (08)	0.011 (004)
182.97 (15)	0.014 (005)	–	–
221.48 (03)	2.69 (03)	2.72 (08)	2.61 (03)
273.35 (04)	0.92 (01)	1.00 (05)	0.95 (02)
280.66 (12)	0.015 (002)	–	0.016 (003)
332.87 (01)	0.024 (012)	0.108 (005)	0.023 (007)
401.13 (09)	0.108 (010)	0.109 (009)	0.109 (007)
454.98 (10)	0.008 (004)	–	–
470.01 (17)	0.031 (010)	–	0.032 (010)
554.34 (02)	84.89 (97)	84.8 (1.6)	85.00 (80)
599.85 (16)	0.02 (01)	0.16 (009)	–
606.37 (02)	1.44 (02)	1.45 (04)	1.42 (02)
619.10 (01)	51.84 (61)	51.6 (1.5)	51.90 (50)
698.37 (02)	33.82 (40)	33.8 (9)	33.80 (40)
734.25 (18)	0.009 (004)	$\leq$ 0.01	–
735.60 (12)	0.072 (008)	0.09 (01)	0.09 (03)
776.53 (02)	100	100	100
827.81 (01)	28.92 (24)	28.7 (9)	28.90 (30)
952.03 (02)	0.46 (01)	0.44 (02)	0.45 (01)
1007.63 (02)	1.57 (02)	1.57 (04)	1.53 (02)
1044.06 (02)	33.28 (39)	32.8 (5)	33.40 (30)
1072.46 (07)	0.102 (009)	0.095 (015)	0.11 (01)
1081.33 (02)	0.756 (014)	0.74 (02)	0.76 (02)
1099.96 (66)	0.010 (009)	0.007 (003)	–
1173.31 (04)	0.02 (01)	0.021 (009)	0.04 (02)
1180.26 (07)	0.112 (007)	0.103 (009)	0.11 (01)
1317.45 (03)	32.96 (39)	32.2 (6)	32.50 (40)
1427.86 (03)	–	–	0.011 (005)
1474.86 (03)	19.84 (24)	19.9 (3)	19.80 (30)
1650.37 (04)	0.90 (01)	0.947 (008)	0.87 (01)
1779.72 (07)	0.130 (003)	0.138 (015)	0.136 (004)
1871.81 (09)	0.049 (002)	0.03 (01)	0.05 (02)
1956.83 (11)	0.041 (002)	0.04 (02)	0.043 (002)

Table (2) The β branching ratios, log ft values, spin and parity assignments for levels in ^{82}kr.

Energy level (keV)	Q_{value} $Q_\beta = 3092.5$ (keV)	$\sum I_\gamma$ feed	$\sum I_\gamma$ decay	$\sum I_\gamma$ decay $-I_\gamma$ feed	B.R %	log ft	J^π
776.53	2315.97	101.16	100.00	–	–	–	2^+
1474.90	1617.60	53.18	53.66	0.482	0.398	9.47	2^+
1820.59	1271.91	32.93	33.28	0.348	0.29	9.14	4^+
1956.79	1135.71	0.21	0.15	–	–	–	2^+
2093.96	998.54	84.92	85.88	0.953	0.79	8.43	3^+
2426.90	665.58	2.82	2.86	0.04	0.04	8.74	4^+
2547.36	545.14	0.097	0.102	0.005	0.004	9.76	3^+
2556.39	536.20	0.903	0.995	0.092	0.076	8.45	4^+
2648.37	444.15	0.035	117.55	117.511	97.00	5.06	4^-
2828.14	264.43	0.014	1.74	1.723	1.42	6.12	5^-
2920.55	171.95	–	0.01	0.01	0.008	7.68	6^+
3011.31	81.35	–	0.022	0.022	0.018	6.58	5^+

Table(3) K-shell internal conversion coefficients of transitions in ^{82}Kr.

Energy (keV)	$J_i^\pi \rightarrow J_f^\pi$	Experimental $\alpha_k(\times 10^3)$	Theoretical $\alpha_k(\times 10^3)$			Deduced Multi-polarity
			E1	E2	M1	
554.34	$4_1^- \rightarrow 3_1^+$	0.848 (23)	0.793	2.60	1.57	*E*1
619.10	$3_1^+ \rightarrow 2_2^+$	1.60 (40)	0.60	1.86	1.34	*E*2/*M*1
698.37	$2_2^+ \rightarrow 2_1^+$	1.25 (33)	0.41	1.13	0.93	*E*2/*M*1
776.53	$2_1^+ \rightarrow 0_1^+$	0.84 (22)	0.354	0.84	0.71	*E*2
827.81	$4_1^- \rightarrow 4_1^+$	0.34 (57)	0.32	0.83	0.71	*E*1
1044.06	$4_1^+ \rightarrow 2_1^+$	0.40 (16)	0.18	0.42	0.39	*E*2
1317.45	$3_1^+ \rightarrow 2_1^+$	0.20 (13)	0.13	0.279	0.269	*E*2/*M*1
1474.86	$2_2^+ \rightarrow 0_1^+$	0.17 (43)	0.10	0.197	0.196	*E*2/*M*1

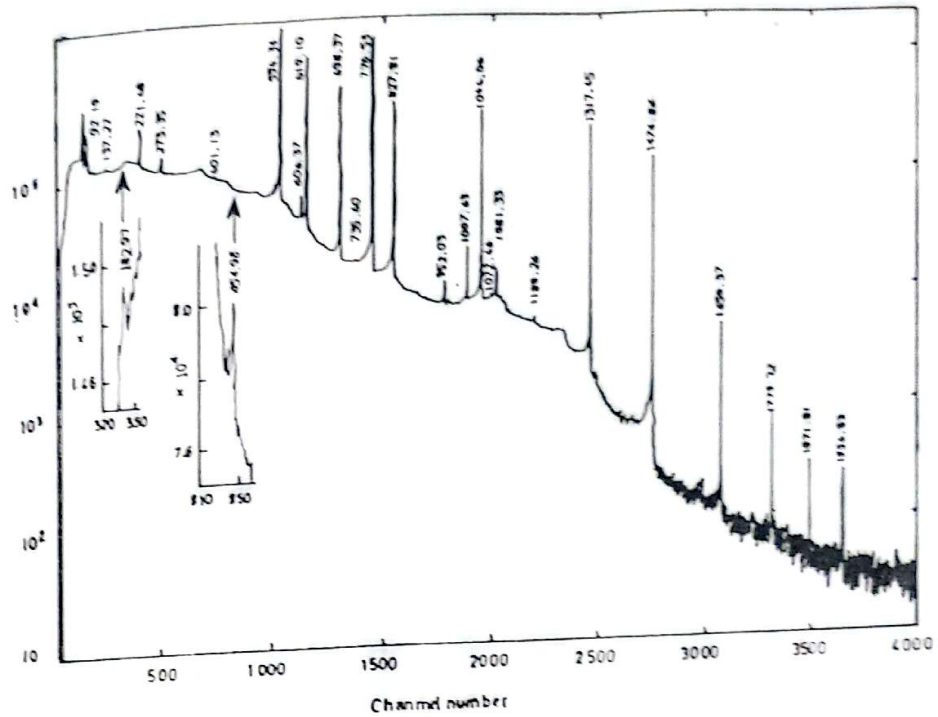

Fig. (1) γ - ray singles spectrum of ^{82}Br decay

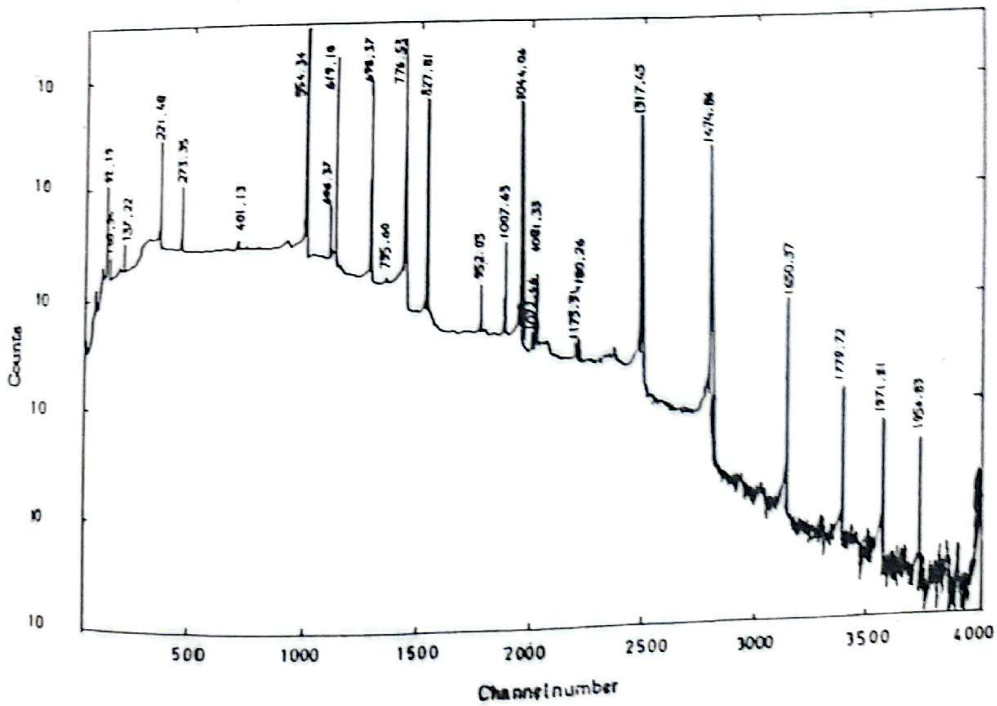

Fig.(2) Compton suppression spectrum of ^{82}Br decay

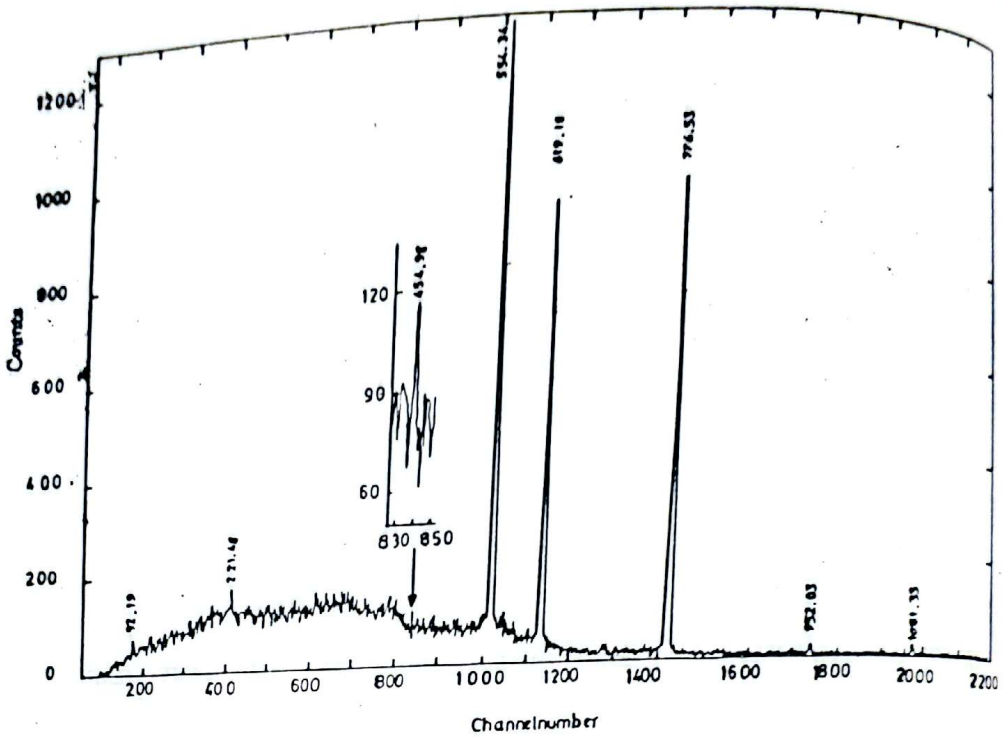

Fig. (3) ^{82}Br spectrum in coincidence with the 698KeV γ - transition

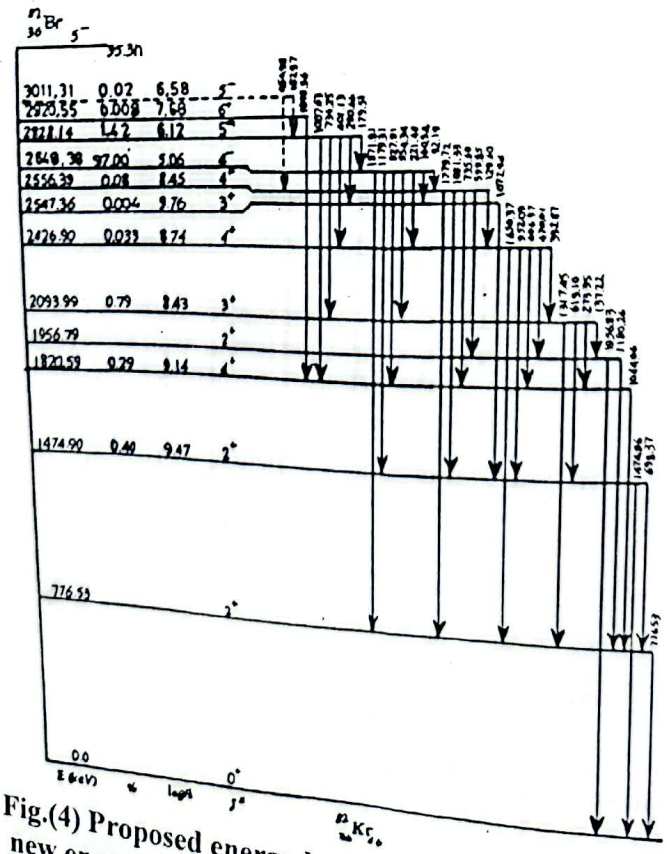

Fig.(4) Proposed energy level scheme for ^{82}Kr with new energy level and transitions marked as dashed lines

مجلة ابن الهيثم للعلوم الصرفة والتطبيقية المجلد 18 (4) 2005

التهيج التجميعي للنظير Kr- 82

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الخلاصة

تم بناء مخطط مستويات الطاقة للنظير Kr- 82 أعتماد على قياسات الطيف المنفرد وطيف التطابق وطيف كومبتن .

أستخدمت كواشف الجرمانيوم النقي لقياسات أكثر دقة لطاقة أشعة كاما ولعدة أنتقالات ناتجة من أضمحلال النظير المشع Br - 82 الى النظير Kr-82 . من مجموع ست وثلاثون طاقة تم ملاحظتها أثنان منهما لأول مرة وجدت بطاقتهما , (454.98, 182.97)KeV وعلى اساسها اعتبر المستوى 3001.31 KeV جديد وبرمة مقداره (5).

حسبت قيم الطاقات وشدتها النسبية وتم تعيين قيم log ft لكل مستوى في مستويات الطاقة والبرم والتماثل النووي فضلا" عن المستوى الجديد (5).