ANSEL Experiment MB Gas Proportional Counter (PC)

Experimental Tasks

Set up the detector, electronics and data acquisition, a procedure similar to that followed in previous experiments with other detectors. This detector is a gas (Kr) amplification (proportional) counter that is used in the Mössbauer experiment. Note the complex detector response to photons.

1. **Slowly** power up the PC (+1800V as noted on detector), as well as the NIM electronics.
2. Place a ^{133}Ba, a ^{57}Co, and a ^{60}Co γ/X-ray source close to the detector or into the holder between detector and velocity drive.
3. On the scope, follow the analog pulse along the slow circuit (from Tennelec preamp to ORTEC 572 main amp). Record the signal shapes in the log book. Draw a block di-agram of the electronics.
4. Select a long enough integration/differentiation time for the main amp.
5. On the scope, inspect the output signals of the main amp. If necessary, adjust BLR and pole-zero.
6. Set up a NIM trigger signal for the data acquisition (DAQ) and check proper relative timing on the scope. Use a *very low threshold* on the TSCA discriminator.
7. For the ^{133}Ba calibration source, check the provided tables and schemes for expected intense X-ray line(s). Attempt to discover them on the scope screen. Change the main amp gain to cover approximately the DDC-8 (0 - 2) Volt range. (Use this gain for a first exploratory spectrum measurement.)
8. Feed the analog signal to analog input (Ch_0) of the DAQ. Feed the NIM signal to the trigger input (NIM_IN_0) of the DAQ.
9. Start the DAQ according to the DDC-8 quick setup checklist.
10. Determine the "zero bin" of the DDC-8 amplitude scale by disconnecting the analog input temporarily.
11. Accumulate, display and save a γ/X ray energy spectrum in histogram form.
12. Adjust the main amplifier gain controls such that an estimated photon energy of E = (30-50) keV corresponds to approximately the middle of the DDC-8 full scale.
13. Perform a measurement with the ^{57}Co source, which should give rise to the 14.4-keV y-ray from the daughter ^{57}Fe.

Next, perform a series of measurements of the X-ray spectra for ^{133}Ba and ^{57}Co sources with several thin absorbers between source and detector. These measurements will ascertain, or modify, tentative energy assignments made in the preceding measurements. For the following measurements, keep accurate record of the running time.

14. With the gain settings determined in the previous measurements, accumulate a ^{133}Ba X-ray "Master" spectrum with good statistics. Record accurately the running time of this measurement.
15. With an external ORTEC counter/scaler measure the mean number of counts/s during the previous Master and each of the following data taking runs.
16. Perform a measurement with a thick Pb absorber from the absorber set, in order to determine the counter background.
17. From the absorber set choose two thin absorbers for which a substantial absorption can be expected for the low-energy γ- and X rays.
    Base your absorber choice on the expected transmission deduced from the provided catalog of transmission coefficients for various materials. Include Al and Pb absorbers.
18. (Optional) Normalize a precision pulser to a tentatively identified γ– or X-ray line, e.g., the 14.4-keV line associated with the ^{57}Co source (see provided level scheme).

Report/Data Analysis (part of report on MB effect**)**

1. Discuss *briefly* the functionality of the counter. For example, explain what advantages Kr offers as a counter gas, as opposed to the more commonly used Ar or organic vapors? What is the purpose of the detector Be entrance window?

2. Identify in the measured spectra for the ^{133}Ba and ^{57}Co sources the prominent spectral features and correlate their channel positions (ch#) with the known energies. In the data analyses keep **track of experimental errors**.

3. Generate a calibration table of the positively identified prominent spectral features from these sources, i.e., list energy (E_X or E_γ) *vs.* experimental channel number (ch#) for these features.

4. Perform a least-squares fit for the calibration data E (ch#) and include the best-fit line in calibration table and plot. Keep track of uncertainties.

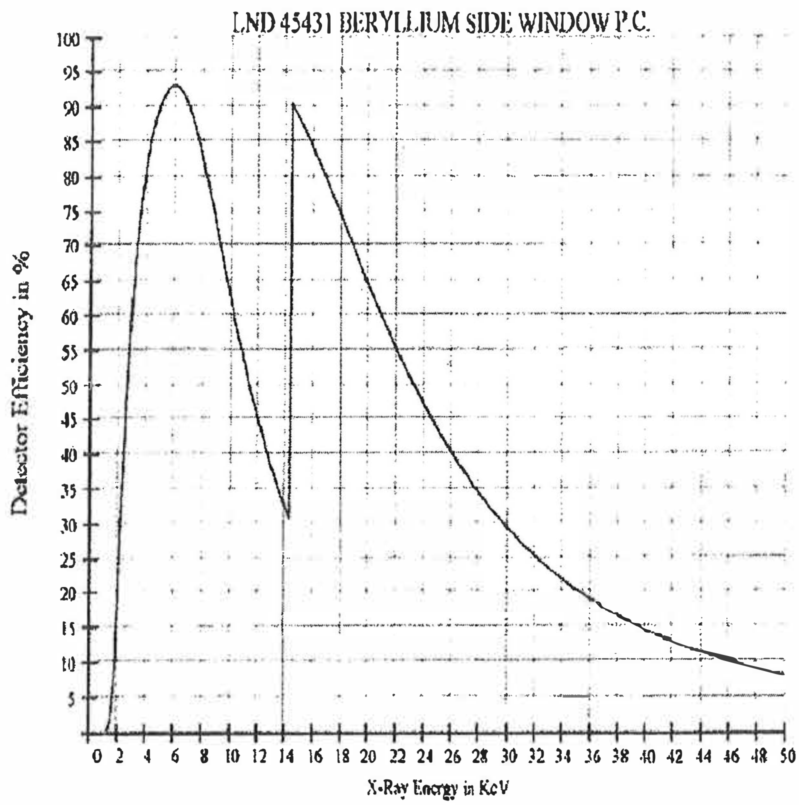
5. Compare the above calibration with that corresponding to the pulser linearity test.

6. Explain the different attenuations of spectral lines obtained with absorbers placed between source and detector. Identify the origin of the dominant low-energy structure in the spectrum.

7. From the count rates measured with the counter/scaler, argue for which, if any, of the runs with absorbers dead time effects need to be considered. Obtain from the TA the fixed DDC-8 dead/busy time per event, which is the dominant component.

Reading Assignments: Knoll, Ch 6 I-IV; Ch 4 VIIA-C; Tables of X-ray energies.

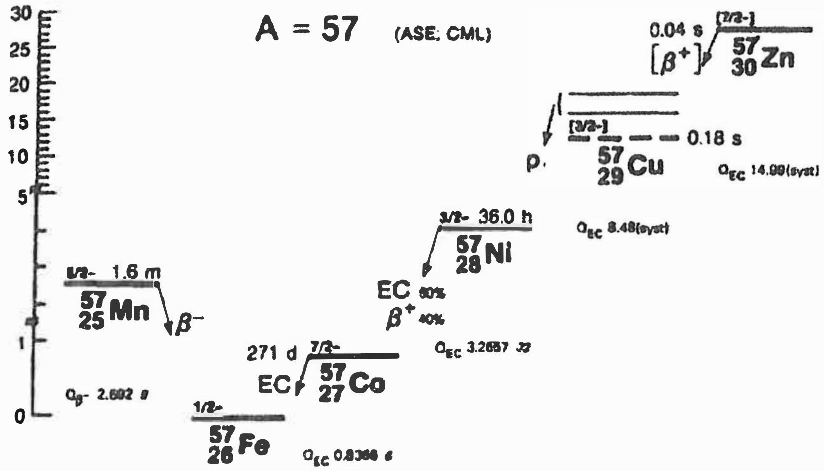
Detector window: berillium 23mg/cm^2

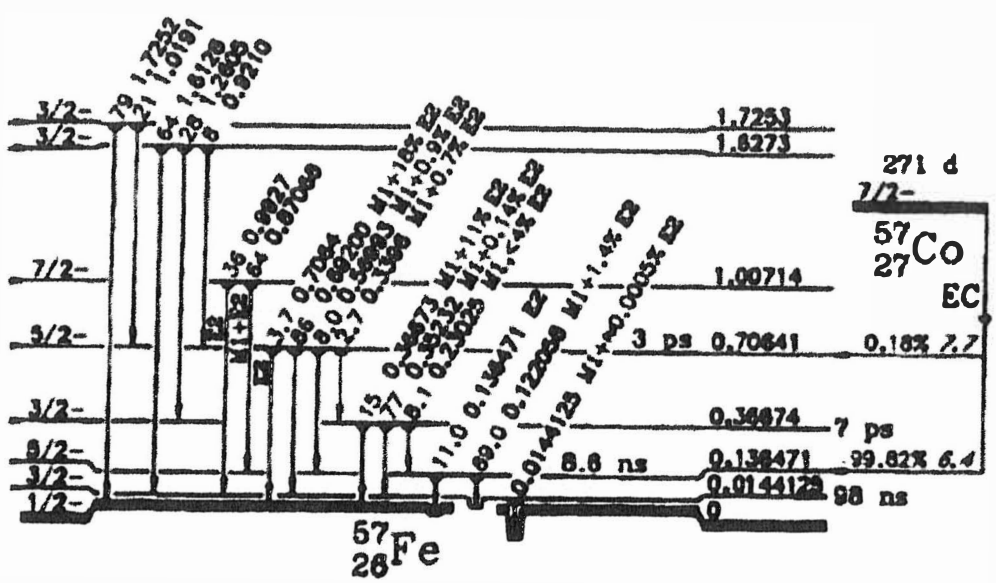


Energies in keV of X-ray emission lines *(https://xdb.lbl.gov/Section1/Table_1-2.pdf.*

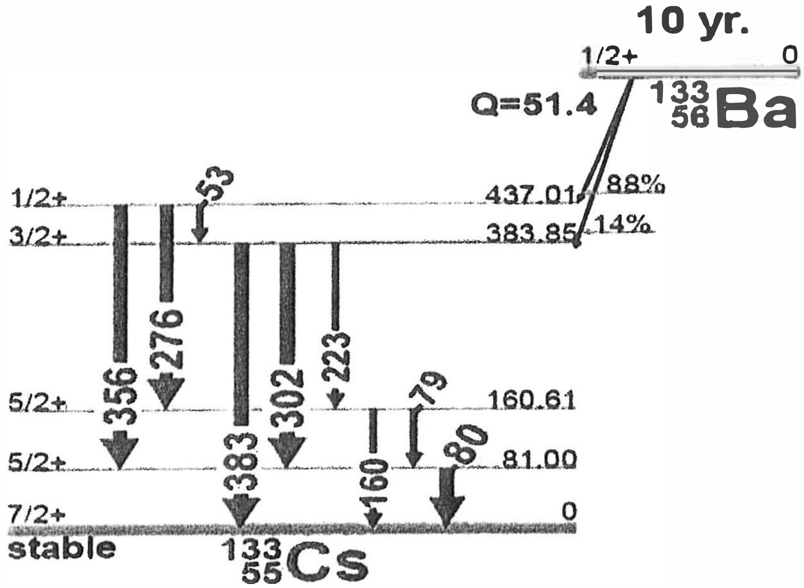
Element	$K\alpha_1$	$K\alpha_2$	$K\beta_1$	$L\alpha_1$	$L\alpha_2$	$L\beta_1$	$L\beta_2$	$L\gamma_1$	$M\alpha_1$
22 Ti	4,510.84	4,504.86	4,931.81	452.2	452.2	458.4			
23 V	4,952.20	4,944.64	5,427.29	511.3	511.3	519.2			
24 Cr	5,414.72	5,405.509	5,946.71	572.8	572.8	582.8			
25 Mn	5,898.75	5,887.65	6,490.45	637.4	637.4	648.8			
26 Fe	6,403.84	6,390.84	7,057.98	705.0	705.0	718.5			
27 Co	6,930.32	6,915.30	7,649.43	776.2	776.2	791.4			
28 Ni	7,478.15	7,460.89	8,264.66	851.5	851.5	868.8			
29 Cu	8,047.78	8,027.83	8,905.29	929.7	929.7	949.8			
30 Zn	8,638.86	8,615.78	9,572.0	1,011.7	1,011.7	1,034.7			
31 Ga	9,251.74	9,224.82	10,264.2	1,097.92	1,097.92	1,124.8			
32 Ge	9,886.42	9,855.32	10,982.1	1,188.00	1,188.00	1,218.5			
33 As	10,543.72	10,507.99	11,726.2	1,282.0	1,282.0	1,317.0			
34 Se	11,222.4	11,181.4	12,495.9	1,379.10	1,379.10	1,419.23			
35 Br	11,924.2	11,877.6	13,291.4	1,480.43	1,480.43	1,525.90			
36 Kr	12,649	12,598	14,112	1,586.0	1,586.0	1,636.6			
37 Rb	13,395.3	13,335.8	14,961.3	1,694.13	1,692.56	1,752.17			
38 Sr	14,165	14,097.9	15,835.7	1,806.56	1,804.74	1,871.72			
39 Y	14,958.4	14,882.9	16,737.8	1,922.56	1,920.47	1,995.84			
40 Zr	15,775.1	15,690.9	17,667.8	2,042.36	2,039.9	2,124.4	2,219.4	2,302.7	

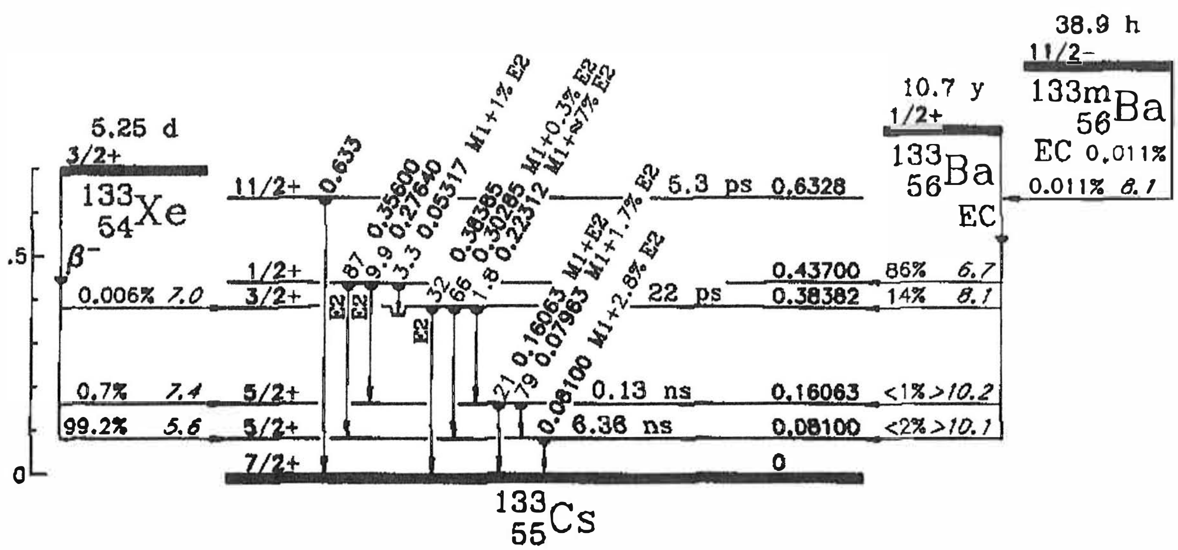
Data Graphs for γ-and X ray sources





^{133}Ba(10 yr.) Decay Scheme





$^{133}_{56}$Ba

$^{133}_{56}Ba_{77}$

1 Decay Scheme

Ba-133 disintegrates by electron capture to Cs-133 via the excited states of 437 keV and of 383 keV .
Le baryum 133 se désintègre par capture électronique vers des niveaux excités de 437 et 383 keV du césium 133.

2 Nuclear Data

$T_{1/2}(^{133}Ba)$: 10,540 (6) a
$Q^{+}(^{133}Ba)$: 517,4 (10) keV

2.1 Electron Capture Transitions

	Energy keV	Probability × 100	Nature	lg ft	P_K	P_L	P_M
$\epsilon_{0,4}$	80,4 (10)	86,2 (5)	Allowed	6,68	0,672 (5)	0,252 (4)	0,0612 (13)
$\epsilon_{0,3}$	133,6 (10)	13,7 (4)	Allowed	8,07	0,7734 (21)	0,1761 (15)	0,0408 (8)
$\epsilon_{0,2}$	356,8 (10)	< 0,3	2nd Forbidden	> 10,6	0,79 (3)		
$\epsilon_{0,1}$	436,4 (10)	< 0,7	2nd Forbidden	> 10,6	0,88 (4)		
$\epsilon_{0,0}$	517,4 (10)	< 0,0005	Uniq. 2ndForbidden	> 13,9			

2.2 Gamma Transitions and Internal Conversion Coefficients

	Energy keV	$P_{\gamma+ce}$ × 100	Multipolarity	α_K	α_L	α_{MNO}	α_T
$\gamma_{4,3}$(Cs)	53,1622 (6)	15,0 (4)	M1+2,2(13)%E2	4,93 (10)	0,86 (3)	0,226 (8)	6,02 (18)
$\gamma_{2,1}$(Cs)	79,6142 (12)	7,34 (17)	M1+0,09(9)%E2	1,515 (30)	0,204 (5)	0,0530 (11)	1,77 (4)
$\gamma_{1,0}$(Cs)	80,9979 (11)	90,1 (16)	M1+2,23(4)%E2	1,46 (3)	0,220 (5)	0,0570 (14)	1,74 (4)
$\gamma_{2,0}$(Cs)	160,6121 (16)	0,84 (3)	M1+62(12)%E2	0,24 (3)	0,054 (7)	0,014 (3)	0,31 (4)

	Energy keV	$P_{\gamma+ce}$ × 100	Multipolarity	α_K	α_L	α_{MNO}	α_T
$\gamma_{3,2}$(Cs)	223,2370 (13)	0,498 (6)	M1+1,3(2)%E2	0,0853 (20)	0,0113 (3)	0,00292 (6)	0,0995 (30)
$\gamma_{4,2}$(Cs)	276,3992 (12)	7,57 (5)	E2	0,0461 (9)	0,00855 (17)	0,00225 (5)	0,0569 (12)
$\gamma_{3,1}$(Cs)	302,8512 (5)	19,15 (14)	M1+0,05(6)%E2	0,0381 (8)	0,00496 (10)	0,00128 (3)	0,0443 (9)
$\gamma_{4,1}$(Cs)	356,0134 (7)	63,64 (20)	E2	0,0211 (4)	0,00351 (7)	0,00092 (30)	0,0256 (5)
$\gamma_{3,0}$(Cs)	383,8491 (12)	9,12 (6)	E2	0,0169 (3)	0,00273 (5)	0,00071 (2)	0,0203 (4)

3 Atomic Data

3.1 Cs

ω_K : 0,894 (4)
$\bar{\omega}_L$: 0,104 (5)
n_{KL} : 0,895 (4)

3.1.1 X Radiations

		Energy keV		Relative probability
X_K				
	$K\alpha_2$	30,625		54,13
	$K\alpha_1$	30,973		100
	$K\beta_3$	34,92	}	
	$K\beta_1$	34,987	}	
	$K\beta_5''$	35,245	}	29
	$K\beta_5'$	35,259	}	
	$K\beta_2$	35,818	}	
	$K\beta_4$	35,907	}	7,33
	$KO_{2,3}$	35,972	}	
X_L				
	$L\ell$	3,8		
	$L\gamma$	– 5,7		

3.1.2 Auger Electrons

	Energy keV	Relative probability
Auger K		
KLL	24,41 – 25,80	100
KLX	29,00 – 30,96	47,2
KXY	33,51 – 35,95	5,56
Auger L	2,5 – 5,6	

4 Electron Emissions

		Energy keV	Electrons per 100 disint.
e_{AL}	(Cs)	2,5 - 5,6	138,0 (15)
e_{AK}	(Cs)		14,2 (6)
	KLL	24,41 - 25,80 }	
	KLX	29,00 - 30,96 }	
	KXY	33,51 - 35,95 }	
$ec_{4,3\ K}$	(Cs)	17,1776 (6)	10,6 (3)
$ec_{2,1\ K}$	(Cs)	43,6296 (12)	4,01 (9)
$ec_{1,0\ K}$	(Cs)	45,0133 (11)	48,1 (11)
$ec_{4,3\ L}$	(Cs)	47,45 - 48,15	1,84 (7)
$ec_{4,3\ MNO}$	(Cs)	51,94 - 53,08	0,484 (18)
$ec_{2,1\ L}$	(Cs)	73,9 - 74,6	0,541 (17)
$ec_{1,0\ L}$	(Cs)	75,29 - 75,79	7,25 (18)
$ec_{2,1\ MNO}$	(Cs)	78,40 - 79,53	0,140 (5)
$ec_{1,0\ MNO}$	(Cs)	79,78 - 80,92	1,88 (5)
$ec_{2,0\ K}$	(Cs)	124,6274 (16)	0,15 (2)
$ec_{4,2\ K}$	(Cs)	240,4143 (12)	0,330 (7)
$ec_{3,1\ K}$	(Cs)	266,8862 (5)	0,70 (2)
$ec_{4,2\ L}$	(Cs)	270,69 - 271,39	0,0612 (13)
$ec_{3,1\ L}$	(Cs)	297,14 - 297,85	0,091 (2)
$ec_{4,1\ K}$	(Cs)	320,0283 (7)	1,31 (3)
$ec_{3,0\ K}$	(Cs)	347,8639 (12)	0,151 (3)
$ec_{4,1\ L}$	(Cs)	350,30 - 351,01	0,218 (4)
$ec_{4,1\ MNO}$	(Cs)	354,80 - 355,93	0,57 (1)

5 Photon Emissions

5.1 X-Ray Emissions

		Energy keV	Photons per 100 disint.	
XL	(Cs)	3,8 — 5,7	16,0 (8)	
$XK\alpha_2$	(Cs)	30,625	34,0 (4)	} $K\alpha$
$XK\alpha_1$	(Cs)	30,973	62,8 (7)	}
$XK\beta_3$	(Cs)	34,92 }		
$XK\beta_1$	(Cs)	34,987 }	18,2 (2)	$K'\beta_1$
$XK\beta_5''$	(Cs)	35,245 }		
$XK\beta_5'$	(Cs)	35,259 }		

		Energy keV	Photons per 100 disint.	
$XK\beta_2$	(Cs)	35,818 }		
$XK\beta_4$	(Cs)	35,907 }	4,6 (1)	$K'\beta_2$
$XKO_{2,3}$	(Cs)	35,972 }		

5.2 Gamma Emissions

	Energy keV	Photons per 100 disint.
$\gamma_{4,3}$(Cs)	53,1622 (6)	2,14 (3)
$\gamma_{2,1}$(Cs)	79,6142 (12)	2,65 (5)
$\gamma_{1,0}$(Cs)	80,9979 (11)	32,9 (3)
$\gamma_{2,0}$(Cs)	160,6121 (16)	0,638 (4)
$\gamma_{3,2}$(Cs)	223,2368 (13)	0,453 (3)
$\gamma_{4,2}$(Cs)	276,3989 (12)	7,16 (5)
$\gamma_{3,1}$(Cs)	302,8508 (5)	18,34 (13)
$\gamma_{4,1}$(Cs)	356,0129 (7)	62,05 (19)
$\gamma_{3,0}$(Cs)	383,8485 (12)	8,94 (6)

6 Main Production Modes

{ Ba – 132(n,γ)Ba – 133 σ : 6,5 (8) barns
Possible impurities : Ba – 131,Ba – 140

{ Ba – 132(n,γ)Ba – 133m σ : 0,5 barns
Possible impurities : Ba – 131,Ba – 140

{ Cs – 133(p,n)Ba – 133
Possible impurities : Cs – 132

7 References

- E. I. WYATT, S. A. REYNOLDS, T. H. HANDLEY, W. S. LYON, H. A. PARKER. Nucl. Sci. Eng. 11 (1961) 74
  (Half-life)
- P. BLASI, M. BOCCIOLINI, P. R. MAURENZIG, P. SONA, N. TACCETTI. Nuovo Cim. 50B (1967) 298
  (Gamma-ray emission intensities)
- J. A. BEARDEN. Rev. Mod. Phys. 39 (1967) 78
  (X-ray energies)
- F. LAGOUTINE, Y. LE.GALLIC, J. LEGRAND. Int. J. Appl. Radiat. Isotop. 19 (1968) 475
  (Half-life)
- A. NOTEA, Y. GURFINKEL. Nucl. Phys. A107 (1968) 193
  (Gamma-ray emission intensities)

$^{57}_{27}Co_{30}$

1 Decay Scheme

Co-57 disintegrates by 100% electron capture to the excited levels of 706.42 keV (0.18%), and 136.47 keV (99.82%) in Fe-57.
Le cobalt 57 se désintègre à 100 % par capture électronique principalement vers les niveaux excités de 706 et 136 keV du fer 57.

2 Nuclear Data

$T_{1/2}(^{57}Co)$: 271,80 (5) d
$Q^+(^{57}Co)$: 836,0 (4) keV

2.1 Electron Capture Transitions

	Energy keV	Probability × 100	Nature	lg ft	P_K	P_L	P_M
$\epsilon_{0,4}$	129,6 (4)	0,183 (7)	Allowed	7,69	0,8789 (17)	0,1035 (14)	0,0168 (6)
$\epsilon_{0,3}$	469,2 (4)	< 0,002	2nd forbidden	> 10,8			
$\epsilon_{0,2}$	699,5 (4)	99,82 (20)	Allowed	6,45	0,8875 (16)	0,0963 (13)	0,0154 (5)
$\epsilon_{0,1}$	821,6 (4)	< 0,003	2nd forbidden	> 11,1			
$\epsilon_{0,0}$	836,0 (4)	< 0,00035	2nd forbidden unique	> 12,9			

2.2 Gamma Transitions and Internal Conversion Coefficients

	Energy keV	$P_{\gamma+ce}$ × 100	Multipolarity	α_K	α_L	α_M (10^{-3})	α_T
$\gamma_{1,0}$(Fe)	14,41295 (31)	87,69 (7)	M1+0,0005%E2	7,69 (16)	0,782 (16)	113 (3)	8,58 (18)
$\gamma_{2,1}$(Fe)	122,06079 (12)	87,53 (8)	M1+1,4%E2	0,0212 (5)	0,00208 (5)	0,303 (7)	0,0236 (5)
$\gamma_{2,0}$(Fe)	136,47374 (29)	12,30 (18)	E2	0,133 (3)	0,0136 (3)	1,96 (4)	0,148 (3)
$\gamma_{3,2}$(Fe)	230,27 (3)	0,0004 (4)	M1+0,04%E2	0,00374 (8)	0,000356 (8)	0,0524 (11)	0,00415 (9)

	Energy keV	$P_{\gamma+ce}$ × 100	Multipolarity	α_K	α_L	α_M (10^{-3})	α_T
$\gamma_{4,3}$(Fe)	339,67 (3)	0,0039 (4)	M1+0,7%E2	0,00149 (3)	0,000142 (3)	0,0208 (5)	0,00165 (4)
$\gamma_{3,1}$(Fe)	352,34 (2)	0,0032 (4)	M1+0,06%E2	0,00135 (3)	0,000129 (3)	0,0188 (4)	0,00150 (3)
$\gamma_{3,0}$(Fe)	366,74 (3)	0,0013 (4)	M1+17%E2	0,00160 (5)	0,000153 (5)	0,0223 (7)	0,00178 (6)
$\gamma_{4,2}$(Fe)	569,94 (4)	0,015 (2)	M1+0,94%E2	0,000458 (10)	0,0000434 (9)	0,00631 (14)	0,000508 (12)
$\gamma_{4,1}$(Fe)	692,01 (2)	0,159 (6)	M1+17,8%E2	0,000328 (10)	0,000031 (1)	0,00452 (14)	0,000364 (12)
$\gamma_{4,0}$(Fe)	706,42 (2)	0,0050 (5)	(E2)				

3 Atomic Data

3.1 Fe

ω_K : 0,352 (4)
$\bar{\omega}_L$: 0,0061 (5)
n_{KL} : 1,456 (12)

3.1.1 X Radiations

		Energy keV		Relative probability
X_K				
	$K\alpha_2$	6,39084		50,7
	$K\alpha_1$	6,40384		100
	$K\beta_3$	7,05798	}	
	$K\beta_5''$	7,1081	}	21,4
X_L				
	$L\ell$	0,61		
	$L\beta$	– 0,79		

3.1.2 Auger Electrons

	Energy keV	Relative probability
Auger K		
KLL	5,37 – 5,64	100
KLX	6,16 – 6,40	23,9
KXY	6,91 – 7,10	2,2
Auger L	0,6 – 0,7	302

4 Electron Emissions

		Energy keV	Electrons per 100 disint.
e_{AL}	(Fe)	0,6 - 0,7	252 (3)
e_{AK}	(Fe)		105,2 (13)
	KLL	5,37 - 5,64 }	
	KLX	6,16 - 6,40 }	
	KXY	6,91 - 7,10 }	
$ec_{1,0\ K}$	(Fe)	7,3009 (3)	70,4 (20)
$ec_{1,0\ L}$	(Fe)	13,567 - 13,705	7,16 (20)
$ec_{1,0\ M}$	(Fe)	14,312 - 14,409	1,03 (3)
$ec_{2,1\ K}$	(Fe)	114,9486 (1)	1,81 (4)
$ec_{2,1\ L}$	(Fe)	121,215 - 121,353	0,178 (4)
$ec_{2,1\ M}$	(Fe)	121,968 - 122,057	0,0259 (6)
$ec_{2,0\ K}$	(Fe)	129,3616 (3)	1,42 (4)
$ec_{2,0\ L}$	(Fe)	135,628 - 135,766	0,146 (4)
$ec_{2,0\ M}$	(Fe)	136,381 - 136,470	0,0210 (5)

5 Photon Emissions

5.1 X-Ray Emissions

		Energy keV	Photons per 100 disint.	
XL	(Fe)	0,61 — 0,79	1,55 (13)	
$XK\alpha_2$	(Fe)	6,39084	16,8 (3)	} $K\alpha$
$XK\alpha_1$	(Fe)	6,40384	33,2 (5)	}
$XK\beta_3$	(Fe)	7,05798 }		
$XK\beta_1$	(Fe)	}	7,1 (2)	$K'\beta_1$
$XK\beta_5''$	(Fe)	7,1081 }		
$XK\beta_4$	(Fe)	}		$K'\beta_2$

5.2 Gamma Emissions

	Energy keV	Photons per 100 disint.
$\gamma_{1,0}$(Fe)	14,41295 (31)	9,15 (17)
$\gamma_{2,1}$(Fe)	122,06065 (12)	85,51 (6)
$\gamma_{2,0}$(Fe)	136,47356 (29)	10,71 (15)