# Spectroscopy with oriented nuclei

Diddens, Albert Nomdo

ıate (55M1). It should be
een reported to have two

ɔossible, as follows from
ities.

e anisotropies were cal-
e of fig. V.8.1 with the
ı table V.8.1, $\beta_o$ = 0.60,
ɔ the positon plus $K$-cap-
ı the $K$-capture branch to
intensity of $\gamma_3$ has been
The results are shown in
the measured values for
rom which $\epsilon$ is reproduced

f the gamma rays from
8.1 for $\beta_o = 0.60$, cor-
th $\lambda_1 = 0.5$ and $\lambda_2 = 1$.
l.75 MeV, 2.02 MeV and
ıble V.8.1. The errors
o 2/3 the value deduc-
ɔf $\epsilon$ as given in table

| $\epsilon$ lculated) | $\epsilon$ (measured; see table V.5.1) |
|---|---|
| +0.334 | +0.32 ± 0.01 |
| +0.312 | +0.35 ± 0.03 |
| -0.181 | -0.19 ± 0.08 |
| -0.317 | -0.27 ± 0.13 |
| -0.324 | -0.30 ± 0.11 |
| +0.380 | +0.38 ± 0.035 |

agreement can be reached
ce the calculated angular
· variations in $\lambda_1$ and $\lambda_2$
ılar distribution of some
it should not be infered

from this agreement that the chosen values for $\lambda_1$ and $\lambda_2$ also represent the actual ones (see also reference 56J3).

In this discussion the possibility of a disturbance of the nuclear orientation in one of the levels has been left out of consideration. In section II.5 it was argumented that disturbing effects would be absent if the lifetime of the excited levels is shorter than $10^{-11}$ sec. The 0.845 MeV and the 2.08 MeV level have a lifetime of this order of magnitude (55C1; 54I1; 56T1). Of the other levels no lifetime has been measured yet. Therefore, some other assignments have been tried for the levels with an energy higher than 2.08 MeV, assuming $\epsilon$ and $P_1$ to be somewhat attenuated for the gamma rays deexciting these levels. But if we take into account the data on the relative intensity of the various transitions and on the angular correlation of the gamma rays (the angular correlation is not influenced by this disturbance because the possible intermediate levels are at 0.845 MeV and 2.08 MeV) it turns out that other assignments have to be rejected or are unlikely.

## V.8. Conclusions and discussion

Fig. V.8.1 shows the decay scheme and the assigned spins and parities; the uncertain gamma rays (see table V.3.1) are not drawn. The multipole order of the gamma rays is indicated in the figure; for the transitions between levels with $\Delta I = 0$ or $|\Delta I| = 1$ only the one giving the main contribution is denoted. The mixing ratios $\delta$ for this category of transitions are collected in table V.8.1. For the gamma rays in the decay of $Co^{56}$ possible values and limits of $\delta$ can be found in the preceding section, for the gammas from $Mn^{56}$ the data have been taken from Metzger and Todd (53M1). For the 3.45 MeV level the assignments $I = 2^-$ and $I = 3^-$ are also compatible with the measurements if the improbable mixture of E1+M2 with $\delta = +0.8 \pm 0.1$ or $\delta = +4.5 \pm 0.5$, respectively, is accepted for the 2.61 MeV gamma; if the existence of the once reported 3.47 MeV gamma could be verified, this would favour $I = 2^-$. For the 3.84 MeV level $I = 5^+$, requiring $\delta = +0.04$ for the M1+E2 mixture of the 1.75 MeV gamma, cannot be rejected entirely on the basis of the measurements but the 2.99 MeV gamma, fitting nicely between this level and the 0.845 level, testifies against it. Also the fact that two gamma rays were reported at about 1.75 MeV (55H1) should be remembered in a criticism of the results concerning this level (see at the end of section V.4.3, point e).

The spin and parity of the 2.86 MeV and 2.97 MeV level have

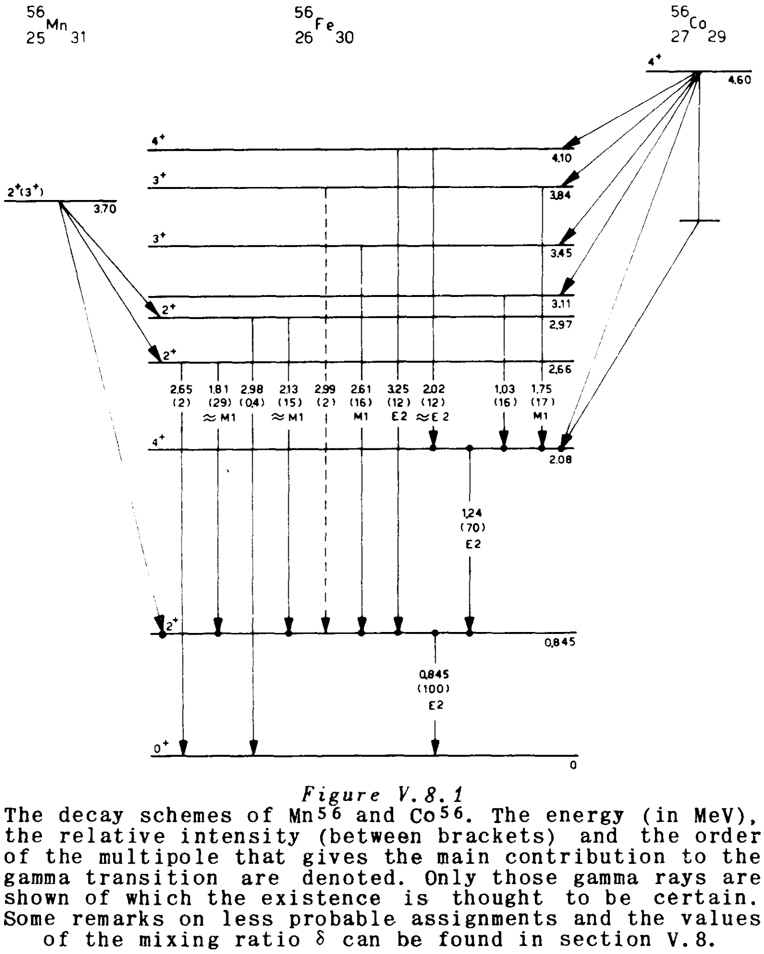



*Figure V.8.1*
The decay schemes of $Mn^{56}$ and $Co^{56}$. The energy (in MeV), the relative intensity (between brackets) and the order of the multipole that gives the main contribution to the gamma transition are denoted. Only those gamma rays are shown of which the existence is thought to be certain. Some remarks on less probable assignments and the values of the mixing ratio $\delta$ can be found in section V.8.

been taken from Metzger and Todd (54M1) and are consistent with the assignments to the levels excited by $Co^{56}$ (55P2).

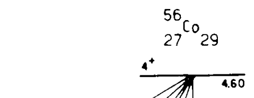
It has been observed in those even-even nuclei whose nucleon numbers are or lie close to magic numbers, that the collective rotational character of the low lying energy levels is replaced by a vibrational one, due to core vibrations (56A1). In the approximation of zero coupling between the particles and the core and assuming harmonic vibrations, these vibrational excitations are at energies of $\hbar\omega$, $2\hbar\omega$, $3\hbar\omega$, etc. above the ground state. The first excited level has spin $2^+$, the second $0^+$, $2^+$, $4^+$ (3 fold

The mix
for gam
$\Delta I = 0$ c
V.7 ((

| Gamm (MeV |
|---|
| 1.75 |
| 2.02 |
| 2.61 |
| 1.81 |
| 2.13 |

degenerate) the thi
transitions betwee
only one phonon jum
hibitted. Because o
should be faster t
estimate (56A1).

Many medium weig
tics (56A1, 55S4, 5
ed, as can be expl
(56W1) coupling be
energies of the sec
ly) to that of the
found to fluctuate
two $2^+$ levels in nu
the ground state, t
dominantly E2 with
crossover transiti
stance $Fe^{58}$ (56F1)).
vealed by Coulomb
lifetime of the fi
10 and 40 compared
For $Fe^{56}$ the rat
cited state is 2.46
MeV gamma is incre
tempting to assign
cleus, also because
the magic number of
first excited vibra
MeV level is conside




The energy (in MeV),
kets) and the order
contribution to the
those gamma rays are
ught to be certain.
ments and the values
d in section V.8.

and are consistent with
$Co^{56}$ (55P2).

ven nuclei whose nucleon
ers, that the collective
nergy levels is replaced
tions (56A1). In the ap-
e particles and the core
vibrational excitations
ove the ground state. The
econd $0^+$, $2^+$, $4^+$ (3 fold

Table V.8.1
The mixing ratio $\delta$ of different multipoles for gamma rays between levels in $Fe^{56}$ with $\Delta I = 0$ or $|\Delta I| = 1$. For details see section V.7 ($Co^{56}$) and reference (53M1) ($Mn^{56}$).

| Gamma (MeV) | $\Delta I$ | $\delta$ (approximately) |
|---|---|---|
| 1.75 | +1 | - 0.03 |
| 2.02 | 0 | +10 |
| 2.61 | -1 | 0 |
| 1.81 | 0 | + 0.15 |
| 2.13 | 0 | - 0.3 |

degenerate) the third $0^+$, $2^+$, $3^+$, $4^+$, $6^+$ (5 fold degenerate). The transitions between them should be of pure E2 nature and since only one phonon jumps are allowed, crossover transitions are prohibitted. Because of their collective nature these E2 transitions should be faster than the Moszkowski-Weisskopf single particle estimate (56A1).

Many medium weight even-even nuclei exhibit these characteristics (56A1, 55S4, 53K1), although some rules are somewhat relaxed, as can be explained by assuming a weak (55S4) or a strong (56W1) coupling between core and particles. The ratio of the energies of the second excited state (having spin $4^+$ or $2^+$ mostly) to that of the first (spin $2^+$ with very few exceptions) is found to fluctuate around 2.2. The gamma transition between the two $2^+$ levels in nuclei having the spin sequence $0^+$, $2^+$, $2^+$ for the ground state, the first and the second excited state is prodominantly E2 with some M1 admixed and is much stronger than the crossover transition to the groundstate (an example is for instance $Fe^{58}$ (56F1)). Another common feature of these nuclei, revealed by Coulomb excitation (56T1), is the reduction of the lifetime of the first excited state by a factor between about 10 and 40 compared to the single particle estimate.

For $Fe^{56}$ the ratio between the energy of second and first excited state is 2.46 and the transition probability of the 0.845 MeV gamma is increased by a factor 15 (56T1). It is therefore tempting to assign some vibrational characteristics to this nucleus, also because both neutron and proton numbers lie close to the magic number of 28. The 0.845 MeV level is taken to be the first excited vibrational state, decaying only by E2. The 2.08 MeV level is considered to be the $4^+$ member of the 3-fold degenerate second excited state. The 4.10 MeV level is taken to represent the $4^+$ member of the 5-fold degenerate third excited state. The latter identification is made on the basis of the almost total E2 character of the 2.02 MeV gamma ($|\delta| \geqq 5$, probably $\delta \approx +10$) and the fact that the transition matrix element for the 3.25 MeV crossover gamma is 0.09 times smaller than that for the 2.02 MeV gamma. The 2.02 MeV gamma thus would connect the $3\hbar\omega$ vibrational band with the $2\hbar\omega$. The identification of both $2^+$ levels at 2.66 MeV and 2.97 MeV as vibrational levels (one of the $2\hbar\omega$, the other of the $3\hbar\omega$ band ?) is less convincing: the E2 contribution is rather low in the 1.81 MeV and 2.13 MeV gamma; but the crossover transitions are weak, indeed.

De onderzoekingen
trekking op het radio
werd bestudeerd ener
gamma coincidentie me
menten met georiënteer
Hoofdstuk II is ge
tie. Na een inleidend
over de door ons gebe
der magnetische hyper
ren zijn hierbij een
handelen over de dete
het algemeen, § 4 zicl
satie van gamma stral
actieve kernen. Een ve
metingen. De laatste
terende effecten.
Enkele problemen v
den worden behandeld i
tie van beta en gamma
over de bepaling van
del van het Compton p
Onder meer wordt het
„snel-langzaam" coinci
In hoofdstuk IV zij
tuur beschreven, n.l.
Het bleek mogelijk met
scintillatoren een coi
bereiken zonder verli
de polarimeter zijn ve
Hoofdstuk V behande
le korte inleidende pa
tie metingen (bij kam
verdeling en de line
straling (lage tempera
conclusies over het v