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Nuclear Moments and Moment Ratios as Determined by Mössbauer Spectroscopy*

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Values are given for Mössbauer effect measurements of nuclear magnetic moments, spectroscopic quadrupole moments, ratios of moments between low lying excited states and the ground state of the same isotope, and ratios of moments between states of different isotopes. Adopted values for moments, obtained by direct selection of specific results or by an averaging process, are presented. The literature has been covered through December, 1974.

Keywords: Mössbauer; nuclear electric quadrupole moments; nuclear magnetic dipole moments.

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1. Introduction

For general discussions of Mössbauer spectroscopy, the reader is referred to a number of review articles in [Go68].¹ For the present purposes, we will make only a few introductory comments.

Measurements of hyperfine interactions obtained by Mössbauer spectroscopy differ from other methods in that one obtains hyperfine energy differences between the nuclear ground state and some excited state, rather than values for a single nuclear level. While ground state moments are generally determined more accurately by other methods, not many techniques are widely applicable to measurements of excited state moments. Therefore, the application of the Mössbauer effect to the measurement of nuclear moments has been widespread.

¹Symbols in brackets indicate literature references.

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If a magnetic hyperfine field H_{hf} is present at the nucleus, then one measures in a Mössbauer spectrum a set of energy value differences given by

$$\begin{aligned}\Delta E_M(I_z^*, I_z) &= -g_N^* \mu_N I_z^* H_{hf} + g_N \mu_N I_z H_{hf}, \\ &= -g_N \mu_N H_{hf} \left[\frac{g_N^*}{g_N} I_z^* - I_z \right], \\ &= -\mu \mu_N H_{hf} \left[R_\mu \frac{I_z^*}{I^*} - \frac{I_z}{I} \right],\end{aligned}\quad (1)$$

where I^* and I are the excited and ground state nuclear spins, I_z^* and I_z are components of I^* and I in the direction of the hyperfine field, μ_N is the nuclear magneton, g_N^* and g_N are the nuclear gyromagnetic ratios in the excited and ground states, and R_μ is the ratio of nuclear magnetic moments

$$R_\mu = \frac{\mu^*}{\mu} = \frac{g_N^* I^*}{g_N I}. \quad (2)$$

Depending on the selection rules governing the nuclear transitions between the $(2I_z^* + 1)$ excited state and $(2I_z + 1)$ ground state levels, one measures a number of such energies, each appearing as an absorption line in the resonance spectrum. A specific example is given in figure 1 where the magnetic hyperfine splitting is shown for a case having $I = 1/2$ and $I^* = 3/2$ applicable, for example, to the Mössbauer resonance in ^{57}Fe or ^{119}Sn . Dipole selection rules allow six possible transitions with the energies shown in the figure. One sees here, or from eq (1), that the relative line positions depend only on the ratio R_μ . This quantity is thus obtained with no external assumptions, and in most cases it is the basic nuclear magnetic moment information provided by the experiment. The ground state moment, if known from other measurements, can then be combined with this ratio to obtain the excited state moment.

The absolute line positions, rather than the relative positions, depend on the product of the moments and the hyperfine field. If H_{hf} is known from other measurements or by calculation, then these positions can be used to determine the moment values. This approach has been used especially for even-even nuclei where $I_z = 0$. Since in this case the ground state moment is zero, one measures only the excited state splitting, and no moment ratio. Some discussion of H_{hf} is thus necessary in order to obtain the excited state moment.

If an electric field gradient is present at the nucleus, then electric quadrupole hyperfine splitting may occur. In a manner similar to the above, a measurement of the quadrupole resonance spectrum can provide the ratio of spectroscopic quadrupole moments $R_Q = Q^*/Q$. This is illustrated in figure 2 for a case where $I = 5/2$ and $I^* = 7/2$ as, for example, in ^{121}Sb or ^{151}Eu . If information concerning the electric field gradient tensor is available, the absolute line positions provide the quadrupole moments directly. Most often this latter approach relies on calculations of the field gradient, which in some cases can be done with reasonable reliability. However, it is important to realize that large "Sternheimer corrections" may be necessary due to a shielding of the field gradient at the nucleus by the local electrons (see [St76a]). In many cases, the magnitude of this shielding is not well known, and this may cause a large error in the derived quadrupole moment.

Moment ratios and moments obtained as described above are listed in table 1, covering all the available

measurements through December 1974. We emphasize that we consider ratios of moments measured by the Mössbauer technique to be the most fundamental experimental quantities since they are obtained without the need of other data. In general, however, we have also given ground state moments obtained from other works and used the listed ratios to obtain excited state moments.

Frequently in the literature measurements of hyperfine energies have been obtained using two different isotopes in the same compound. If the ratio of these energies is calculated, the hyperfine field or electric field gradient cancels and one obtains a ratio of the nuclear moments of those isotopes. This may then be combined with a measured value for one of the moments to obtain the other. Ratios obtained in this way are listed in table 2. These are also cross-referenced to an entry in table 1 where the ratio is used to obtain one of the moments.

Table 1 also indicates adopted values for the ratios and moments. When one measurement appears to be substantially more reliable than other published results due to superior data or analysis, that value has been chosen as the adopted value. In the majority of cases, several measurements of comparable quality exist and an averaging procedure over selected values has been used. Again here, the choice of which values to include in averaging is based on quality of data and of analysis. The final adopted values are summarized for convenience in table 3.

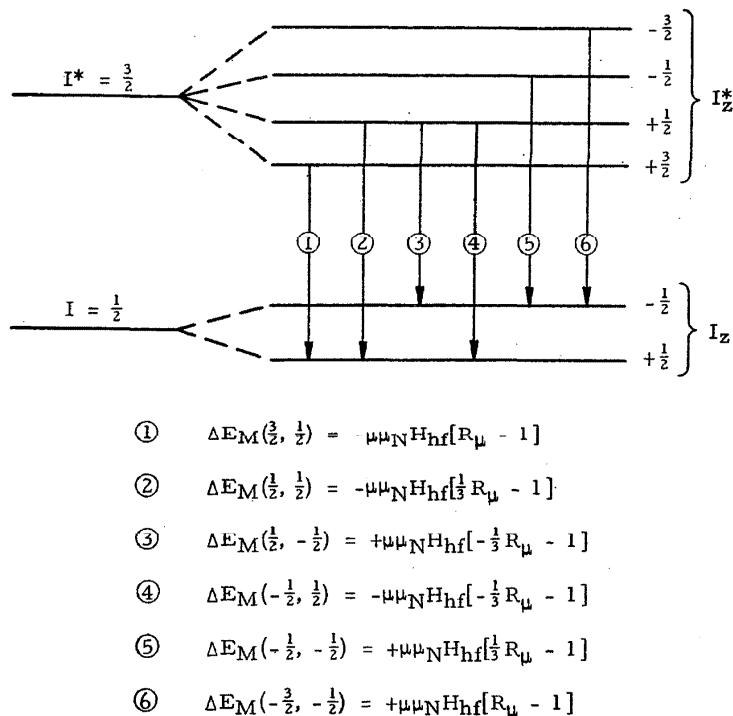
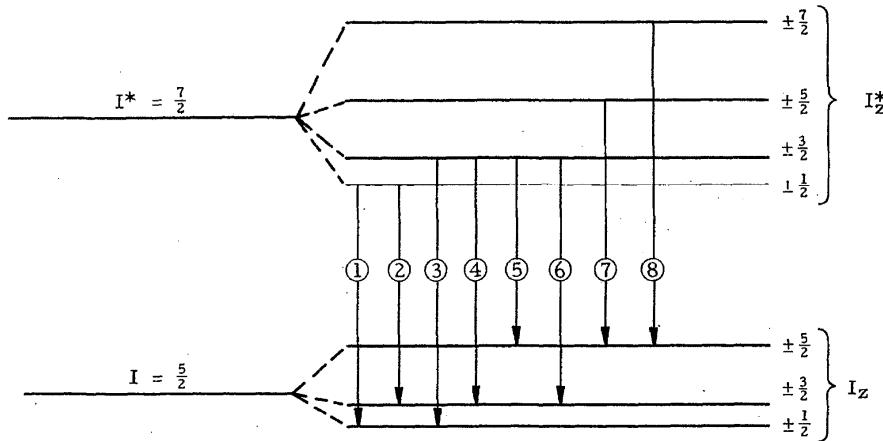


FIGURE 1. Magnetic hyperfine splitting and resonance line positions for $I^* = 3/2 \rightarrow I = 1/2$ transition. In the splitting diagram, the energy level ordering presumes positive values of μ and μ^* .



- ① $\Delta E_Q(\pm \frac{1}{2}, \pm \frac{1}{2}) = e^2 q Q [-\frac{5}{28} R_Q + \frac{1}{5}]$
- ② $\Delta E_Q(\pm \frac{1}{2}, \pm \frac{3}{2}) = e^2 q Q [-\frac{5}{28} R_Q + \frac{1}{20}]$
- ③ $\Delta E_Q(\pm \frac{3}{2}, \pm \frac{1}{2}) = e^2 q Q [-\frac{3}{28} R_Q + \frac{1}{5}]$
- ④ $\Delta E_Q(\pm \frac{3}{2}, \pm \frac{3}{2}) = e^2 q Q [-\frac{3}{28} R_Q + \frac{1}{20}]$
- ⑤ $\Delta E_Q(\pm \frac{3}{2}, \pm \frac{5}{2}) = e^2 q Q [-\frac{3}{28} R_Q - \frac{1}{4}]$
- ⑥ $\Delta E_Q(\pm \frac{5}{2}, \pm \frac{3}{2}) = e^2 q Q [\frac{1}{28} R_Q + \frac{1}{20}]$
- ⑦ $\Delta E_Q(\pm \frac{5}{2}, \pm \frac{5}{2}) = e^2 q Q [\frac{1}{28} R_Q - \frac{1}{4}]$
- ⑧ $\Delta E_Q(\pm \frac{7}{2}, \pm \frac{5}{2}) = e^2 q Q [\frac{1}{4} R_Q - \frac{1}{4}]$

FIGURE 2. Electric quadrupole hyperfine splitting and resonance line positions for $I^* = 7/2 \rightarrow I = 5/2$ transition. The principal component of the electric field gradient tensor is $V_{zz} = eq$, and axial symmetry is assumed. In the splitting diagram, the energy level ordering presumes positive values of Q and Q^* .

2. Error Analysis and Averaging Procedure

Uncertainties, given in parentheses beside the data values, show estimated deviation for the indicated number of trailing significant figures. Thus, $1.065(40) = 1.065 \pm 0.040$. For ratios of moments, uncertainties quoted are those of the original reference. If no value was given there, then none appears here. Moment values X_1 are generally obtained by combining a measured ratio R with a measured value for another moment X_2 , i.e., $X_1 = RX_2$. Uncertainties ΔX_1 are then determined by

$$\left(\frac{\Delta X_1}{X_1}\right)^2 = \left(\frac{\Delta R}{R}\right)^2 + \left(\frac{\Delta X_2}{X_2}\right)^2, \quad (3)$$

where ΔR and ΔX_2 are measured uncertainties. If no value is available for either ΔR or ΔX_2 , then none is given for ΔX_1 . In cases where the moment is not obtained by a ratio, the stated uncertainty is that of the original reference. Averaging has been performed by weighting the measured quantities by the inverse square of the error:

$$X = (\sum \sigma_i^{-2} X_i) / (\sum \sigma_i^{-2}) \quad (4)$$

where $\sigma_i = \Delta X_i$. The probable error $\Delta \bar{X}$ assigned to the average, has been calculated both according to

$$(\Delta \bar{X})^2 = [\sum \sigma_i^{-2}]^{-1}, \quad (5)$$

and

$$(\Delta \bar{X})^2 = [\sum \sigma_i^{-2} (X_i - \bar{X})^2] / [(N - 1) \sum \sigma_i^{-2}], \quad (6)$$

where N is the number of measurements used. The tabulated value for $\Delta \bar{X}$ is the larger of the two. If a value was used in averaging which had no indicated error, then for these purposes it was assigned an error equal to ± 5 in the reported last significant digit.

R_μ A numerical entry indicates a value for the ratio of the magnetic moment of the excited state in question to that of the ground state for the same isotope. In some cases, the derived excited state moment and the assumed ground state moment were given, but not the actual ratio. In those cases (marked by footnote d), the ratio has been derived from the excited and ground state moments and is entered here as the experimental

result. References to ratios of moments between different isotopes of the excited state in some level other than the ground state are indicated in this column by a number preceded by an r (e.g., r33), and all such measured values are listed separately in table 2 under this code number. When listed, moment ratios are to be considered the primary experimental data, with other quantities being derived results.

μ All magnetic moments are in units of nuclear magnetons ($\mu_N = 5.050824(20) \times 10^{-27} JT^{-1}$). Ground state moments are usually obtained by some method other than Mössbauer spectroscopy, but are listed for completeness. This is not intended to be a complete listing of ground state moments, and we only include those here which are used in combination with a measured ratio. All values have been corrected for diamagnetic shielding using Kopfermann's calculations (H. Kopfermann *Nuclear Moments* (translated by E. E. Schneider), Academic Press Inc., New York, 1958). A 5 percent uncertainty was assumed for the diamagnetic shielding correction. When a value for R_μ is listed, the moment has been obtained by combining that ratio with the ground state moment listed in the table. In many cases, the resultant moment differs somewhat from that of the original reference due to the use of a more recent ground state value or our use of the diamagnetic correction. Moments obtained from ratios other than that of the ground

to excited state are arrived at by combining the numerical ratio values listed in table 2 with either a ground state moment from this table, or another adopted value from table 3.

R_Q A numerical entry indicates a value for the ratio of the spectroscopic quadrupole moment in the excited state to that of the ground state in the same isotope. Conventions and notation are the same as for R_μ .

Q All quadrupole moments are in units of barns (1 barn = $10^{-28} m^2$). In all cases, the value listed is the spectroscopic quadrupole moment rather than the intrinsic moment. Unless noted by footnote (n), values are given after correction for the Sternheimer effect. Conventions, notations and provisions are the same as for μ .

References

References to measurements obtained by techniques other than Mössbauer spectroscopy are enclosed in parentheses. Example: (Sc70). If more than one reference is enclosed in parentheses, then the quoted value is a weighted average over all those references. Example: (Ku61, Fe63).

If the same quantity is reported more than once by the same group of authors, all references are given, but the tabulated value is taken as the latest one. Example: Do61, Lo62.

Table 1. Nuclear moment data from Mössbauer spectroscopy

Isotope	Energy	Spin	R_u	u	R_Q	Q	Reference
^{57}Fe	0	1/2		+ 0.090604 (9)			(Sc70)
	14.4	3/2				- 0.19 ^g	Be60a
			- 1.69(5) ^d	- 0.153 (5)			Ha60a
			- 1.694 (20) ^d	0.1535 (18)			Ki60
						+ 0.100(25) ^{g,u}	Ab61
						+ 0.4 ^g	Bu61
						0.32 (6)	Ga62
						> 0	Ka62
						0.18 ^g	De61, La62
			- 1.715 (4) ^a	- 0.1554 (4)			Pr62
			1.69 ^d	0.153		+ 0.28 ^g	We61, We62
							Ch63
						+ 0.15 (1) ^{g,u}	Ei63
						+ 0.23 (5) ^g	Fr63
			1.69 (14)	0.153 (13)			Ni63
						+ 0.28 ^g	St63
			- 1.724 (10)	- 0.1562 (9)			Gr64a
						0.34 ^g	On64
						0.277 ^g	Sh64
			- 1.715 (2) ^a	- 0.1554 (2)			Ko65
			1.7135 (15) ^a	0.15525 (14)			Pe65
			1.715 (3) ^a	0.1554 (3)			Cr67
			- 1.712 (13)	- 0.1551 (12)			Ei67
						+ 0.18 ^{g,u}	Jo67, Jo68
			1.711 (4) ^a	0.1550 (4)			Ke67
						+ 0.20 ^g	No67
						0.25 ^g	Wi67
						0.175 (20) ^g	Ha68
						+ 0.283 (35) ^g	Ar68, Mu68a
						0.24 (4) ^g	Ra68
			1.7142 (33) ^a	0.15531 (30)			So68
			1.701 (8)	0.1541 (7)			Ze68

Table 1. Nuclear moment data from Mössbauer spectroscopy--continued.

Isotope	Energy	Spin	R_{μ}	μ	R_Q	Q	Reference
⁵⁷ Fe	14.4	3/2				+ 0.21 (3) ^{a,g}	Ch69, Ch69b
			- 1.715 (4) ^a	- 0.1554 (4)			F069
			1.7128 (13) ^a	0.15519 (12)		+ 0.21 (3) ^{a,g}	In64, In69
			1.714 (5) ^a	0.1553 (5)		0.22 (6) ^g	La70
						0.20 (3) ^{a,g}	Ro70, Ro70a
						0.16 (3) ^{a,g}	Sw70
						0.18 (2) ^{a,g}	Fr70, Fr71
						+ 0.213 (5) ^{a,g}	Mc71, Mc71a
						0.19 ^g	Se71
			- 1.7145 (5) ^a	- 0.15534 (5)			Vi71
						0.24 ^g	Va72
						0.16 (3) ^g	Ha73
						+ 0.20 (3) ^{a,g}	Tr73
						0.20 ^g	Sp74
			- 1.7142 (4) ^b	- 0.15532 (4) ^b		+ 0.209 (5) ^b	
⁶¹ Ni	136.5	5/2	- 10.8 (11) ^d	- 0.98 (10) ^g			He67b
	0	3/2		- 0.7498 (1)			(Dr64)
						+ 0.162 (15)	(Ch68)
	67.4	5/2	- 0.64 (20)	+ 0.48 (15)			We61a
			- 0.577 (25) ^a	+ 0.433 (19)			Er68
			- 0.563 (82)	+ 0.422 (61)			Sp68, Tr68
			- 0.637 (42)	+ 0.478 (31)			Er69
					< 0		Er69a
			- 0.640 (8) ^a	+ 0.480 (6)	- 1.21 (13) ^c	- 0.20 (3) ^c	Go71
			- 0.642 (10) ^a	+ 0.481 (7)	0.3 (9)	0.05 (15)	Lo68, Lo68a, Lo68b, Lo71
			- 0.637 (11) ^b	+ 0.478 (7) ^b			
⁶⁷ Zn	0	5/2		+ 0.8755 (3)			(Sp67, Sp67a, We53)
	93.3	1/2	+ 0.66 (3) ^d	+ 0.58 (3)			Pe73, Pe73a
⁸³ Kr	0	9/2		- 0.9703 (2)			(Br68)
						+ 0.253 (7) ^U	(Ku61, Fa63)

Table 1. Nuclear moment data from Mössbauer spectroscopy--continued.

Isotope	Energy	Spin	R_{II}	μ	R_Q	Q	Reference
⁸³ Kr	9.4	7/2			1.70(2) ^c	+ 0.430(13) ^{c,u}	Ru66
			+ 0.971(2) ^c	- 0.943(2) ^c			Ca69
					1.98	0.50 ^u	Kr69
			1.03(6)	- 0.99(8)			Gr69
⁹⁹ Tc	0	9/2		+ 5.6807(14)			(Wa52)
						+ 0.34(17) ^u	(Ke53)
⁹⁹ Ru	140.5	7/2	+ 0.64(16) ^d	+ 3.6(8)			Sh73
				- 0.626(13)			(Ma65, Gi73a)
						0.12(3) ^f	Ba72a, Gi74
¹¹⁹ Sn	89.3	3/2	0.455(10)	- 0.284(8) ^a	≥ 3	≥ 0.15 ^g	Ki64a, Ki66
				- 0.30(3) ^g			Ki66
					r1	0.36(7) ^c	Ba72a
			0.456(2) ^c	- 0.285(6) ^a	+ 2.88(6) ^c	> 0.23	Gi73, Gi74
				- 0.285(5) ^b			Gi73a
¹¹⁹ Sn	0	1/2		- 1.0461(3)			(Pr50)
				+ 0.78(6)			Ha60
			0.80(3) ^d	0.83(3)			Bo61
			- 0.648(25) ^d	+ 0.68(4)			Ki61
			- 0.72(3) ^d	+ 0.75(3)			De60, Br62
						- 0.08 ^{g,u}	Bo62
						0.05 ^{g,u}	Co64c
			- 0.68	+ 0.71			He64
				0.67(1)			Go65, Go65a
				0.685(15)			Bo66
¹¹⁹ Sn	23.8	3/2	0.652	0.68			Ku66
			0.70(2)	0.73(2)			Ja67
						- 0.06(2) ^{g,u}	Ru67c
			- 0.64(1)	+ 0.67(1)			Wi68
						- 0.122 ^{g,u}	De70a
			0.658(3) ^d	0.688(3)			Bo71, Bo71a
			- 0.6462(6)	+ 0.676(7)			No71, Ba72
						- 0.062(20) ^{a,g,u}	Ba72a

Table 1. Nuclear moment data from Mössbauer spectroscopy--continued.

Isotope	Energy	Spin	R_{μ}	μ	R_Q	Q	Reference
¹¹⁹ Sn	23.8	3/2			r2	$\pm 0.062(5)^{a,u}$	Mi72, Ba73
			-0.615(9) ^a	+0.643(9)			Br73, Wi73
			-0.6045(15) ^a	+0.6324(15)			Cr73, Cr73a
			-0.605(17) ^b	+0.633(18) ^b		-0.065(5) ^{b,u}	
	89.5	11/2		1.40(8)			Gu72
					r3	-0.14(2)	Be72
¹²¹ Sb	0	5/2		+3.3591(6)			(Co50, Pr51)
						-0.28(6) ^{f,g,u}	Ru67c
	37.2	7/2			1.38(2)	-0.39(8) ^u	Sn66, Ru66a
					1.36(2)	-0.38(8) ^u	Ru67
			+0.700(9) ^d	+2.35(3)			Ru67, Ru67b
			0.748(9) ^{a,d}	2.51(3)			Ru67a
					1.32(2)	-0.37(8) ^u	St70a
			0.729(6) ^{a,d}	2.45(2) ^{a,g}			Ir70, Ir70a
					1.34(1) ^c	-0.38(8) ^{c,u}	St70
			+0.735(9) ^b	+2.47(3) ^b			
¹²⁵ Te	0	1/2		-0.88716(25)			(We53)
	35.5	3/2		+1.92 ^g		-0.16 ^{a,g,u}	Sh63
						0.20(3) ^{a,g,u}	V163
					r4	-0.24 ^{a,u}	Pa67
			-0.84(9) ^a	+0.75(8)			Ul67
			-0.678(23) ^{a,d}	+0.60(2)			Hu64, Fr65, Fr68
						>0	Ku69
						<0 ^a	Ch74
			-0.69(6) ^b	+0.61(5) ^b		-0.200(23) ^{b,u}	
¹²⁷ I	0	5/2		+2.8091(4)			(Po48, Z149, Sh51, Wa51, Ya51)
						-0.79(10) ^u	St59
	57.6	7/2			-0.896(2) ^c	-0.71(9) ^{c,u}	Pe64a
			0.905(16) ^c	2.54(4) ^c			Wo72a
¹²⁹ I	0	7/2		+2.6174(8)			(Wa51)
						-0.55(7) ^u	(Li53)

Table 1. Nuclear moment data from Mössbauer spectroscopy--continued.

Isotope	Energy	Spin	R_u	u	R_Q	Q	Reference
^{129}I	27.8	5/2	+1.085(19) ^d	+2.84(5)			De64
					+1.23(2)	-0.68(9) ^u	De63, Ha64
					+1.234(3) ^a	-0.68(9) ^u	Pa65
			1.0687(11) ^c	+2.797(3) ^c			De70
					1.2385(11) ^a	0.68(9) ^u	Ro72
					1.239(7)	0.68(9) ^u	Ba74
					+1.2380(15) ^b	-0.68(6) ^b	
^{129}Xe	0	1/2		-0.77682(23)			(Br68)
	39.6	3/2			r5	-0.41(4) ^c	Pe64
			-0.87(39)	+0.68(30)			Ca68
			-0.75(12) ^c	+0.58(9) ^c			Va74
^{133}Cs	0	7/2		+2.5786(8)			(Wh73)
						-0.0030(7)	(St71, Ry72)
	81.0	5/2	+1.335(8) ^c	+3.443(21) ^c			Ca68, Ca68a
			1.36(3)	3.51(8)			Ge72
^{141}Pr	0	5/2		+4.162(2)			(Le70a)
						-0.059(4) ^u	(Bl64)
	145.2	7/2	+0.67($\frac{3}{2}$) ^a	+2.80($\frac{12}{6}$)		< 0.3 ^u	Be71a
			+0.67(4) ^a	+2.80(18)			Ka71, Ka71a
			+0.750(45) ^a	+3.12(18)			Gr73
			+0.69(2) ^b	+2.87(9) ^b			
^{145}Nd	0	7/2		-0.654(4)			(Sm65)
	72.5	5/2	+0.489(4)	-0.320(3)			Ka68, Ka70b
^{147}Pm	0	7/2		+2.62(6)			(Bl64, Re66)
						+0.71(21) ^u	(Bu63, Re66)
	91.0	5/2	1.375(3) ^a	3.60(8)	0.8(4)	0.6(3) ^u	Ba70, No71a
			1.371(3) ^a	3.60(8)			Pa71a
			1.373(2) ^b	3.60(5) ^b			
^{147}Sm	0	7/2		-0.813(1)			(Wo66)
						-0.18(3) ^u	(Ro69)
	122.1	5/2	+0.551(31) ^{c,d}	-0.448(25) ^c	+1.7(7) ^{c,d}	-0.31(12) ^{c,u}	Pa70a, Pa71
^{149}Sm	0	7/2		-0.670(6)		+0.058(6) ^u	(Wo66)

Table 1. Nuclear moment data from Mössbauer spectroscopy--continued.

Isotope	Energy	Spin	R_{μ}	μ	R_Q	Q	Reference
^{149}Sm	0	7/2				$< 0.06^{\text{f},\text{u}}$	No67a
						0.060(15) ^{c,f,g,u}	Ei71
	22.5	5/2	+ 0.82 ^d	-0.55			Gr64
			+ 0.93(1)	-0.623(9)		0.40(6) ^{g,u}	Of65b, No67a, Of67
			+ 0.929(1) ^c	-0.623(6) ^c	8.3(21) ^{d,c}	0.50(1) ^{g,c,u}	Ei71
^{152}Sm	121.8	2		0.84(5) ^g			At67
^{154}Sm	81.9	2		0.78(4) ^g		-1.3(5)	Wh69
^{151}Eu	0	5/2		+ 3.4649(23)			(Ev65, Ki70)
						+ 1.14(5) ^{g,u}	(Mu65, Wi65, Gu68)
	21.6	7/2	+ 0.739(7)	+ 2.561(24)			Ba63
			0.74(4)	2.57(15)	1.3(5)	1.5(6) ^u	No63a
			0.74(4)	2.57(15)			Co64
			+ 0.742(1)	+ 2.571(5)			Ki64
					1.64(7)	1.87(11) ^u	No68
			0.7465(6) ^c	2.5865(26) ^c	+ 1.28(4) ^a	+ 1.46(8) ^u	St68, Cr69, St69, Cr72, Cr73a
					1.30(5) ^a	1.48(9) ^u	Ka69, Ka70
					1.30(4) ^a	1.48(8) ^u	Du70
					1.34(3) ^a	1.53(8) ^u	Ch72, Ch74a
					+ 1.312(19) ^b	+ 1.50(7) ^{b,u}	
^{153}Eu	0	5/2		+ 1.5294(7)			(Ev65, Ki70)
						+ 2.90(12) ^u	(Mu65, Wi65, Gu68)
	83.4	7/2	+ 1.18(4)	+ 1.80(6)			Ri69
	97.4	5/2	+ 2.10(15)	+ 3.21(23)			At66b
				2.50(25)			De66a
	103.2	3/2	+ 1.33(5)	+ 2.04(7)			At64
				1.9(2)			De66a
			+ 1.25(4)	+ 1.91(6)			Ri69
			1.336(7) ^a	2.043(11)	0.520(3)	1.51(6) ^u	Ar69, Ar73
			1.336(4) ^a	2.043(6)			Cr72, Cr73a
			+ 1.336(3) ^b	2.043(5) ^b			
^{155}Gd	0	3/2		- 0.2584(5)		+ 1.59(16) ^u	(Un69)

Table 1. Nuclear moment data from Mössbauer spectroscopy--continued.

Isotope	Energy	Spin	R_u	u	R_Q	Q	Reference
^{155}Gd	86.5	5/2	-3.5(5)	+ 0.90(13)			De66
			+ 2.09(20) ^d	- 0.54(5)	0.20(10)	0.31(16) ^u	Bl68, Bl68a
			+ 2.27(7)	- 0.587(17)	0.346(12) ^a	0.54(6) ^u	To68
			+ 2.03(2)	- 0.525(4)	0.12(1) ^a	0.187(16) ^u	Ba69a
				+ 2.17(22)		+ 3.4(5) ^u	Ba69
					0.12(2) ^a	0.19(4) ^u	Ka72a
			2.058(13) ^a	0.532(4)	0.087(6) ^a	0.136(16) ^u	Ar73, Ar74
			2.005(28) ^a	0.518(7)	0.35(6) ^a	0.55(?) ^u	Bo74
			+ 2.049(20) ^b	- 0.529(5) ^b	0.14(5) ^b	0.22(8) ^{b,u}	
			[-0.51(16)] ^{d,h}	[+0.13(4)] ^h	0.9(1) ^a	1.40(21) ^{a,u}	Bl68, Bl68a
$^{105.3}$	3/2		[+1.50(6)] ^{d,h}	[-0.39(6)] ^h			
			[-0.55(5)] ^h	[+0.142(13)] ^h	1.00(3) ^a	1.56(26) ^{a,u}	Ar73, Ar74
			[+2.01(5)] ^h	[-0.519(13)] ^h	0.99(3) ^b	1.57(16) ^{b,u}	
^{156}Gd	88.9	2		0.792(14) ^{g,a}			Pe68
					r6	1.21(13) ^u	St67
					r6	1.89(23) ^u	To68
			r8	+ 0.773(8) ^a	r6	- 2.40(24) ^{c,u}	Ar74
^{157}Gd	0	3/2		- 0.3388(7)			(Ba69b)
					r7	2.00(26) ^{f,u}	Pr68
^{160}Gd	64.0	5/2			1.78(4) ^a	3.6(5) ^u	Pr68
			+ 1.515(7)	- 0.5133(26)			Go72
					1.80(3) ^a	3.6(5) ^u	Ar74
^{158}Gd	79.5	2		0.77(4) ^g			Fi67
					r9	1.30(14) ^u	St67
					r10	1.34(14) ^u	St67
^{159}Tb	0	3/2		+ 2.008(4)			(Ba65)
							At66a
^{160}Dy	58.0	5/2		[0.80(5)] ^h	[+1.60(10)] ^h		
				[1.15(5)] ^h	[+2.29(10)] ^h		
			r11	0.96(8)			Co64
			r11	0.74(8) ^{a,g}			Co65
	86.8	2	r11	0.78(5) ^a			Of65
			r11	0.77(4) ^b			

Table 1. Nuclear moment data from Mössbauer spectroscopy--continued.

Isotope	Energy	Spin	R_{μ}	μ	R_Q	Q	Reference
¹⁶¹ Dy	0	5/2		-0.479 (5)			(Fe74)
	25.6	5/2	-1.14 (27) ^d	+0.54 (13)		+2.35 (16)	(El57, Eb67)
					1.30	3.06 ^e	Ba61
			-1.2 (1)	+0.57 (5)	1.20 (5)	2.82 (23)	Ba64, Ba64a
			-1.21 (2)	+0.580 (11)	0.98 (3)	2.30 (16)	No65
			-1.2 (1)	+0.57 (5)	0.85 (10)	2.00 (14)	Lu66
			-1.18 (3)	+0.565 (16)	1.03 (6)	2.42 (22)	Of66
			-1.21 (2)	+0.580 (11)	+1.01 (3)	+2.37 (18)	Bo67
			1.22 (3)	+0.584 (15)	1.00 (3)	2.35 (17)	Cr68
			-1.241 (4) ^a	+0.594 (6)	0.95 (10)	2.2 (3)	Of65a, Kh70
			-1.243 (10) ^a	+0.595 (8)	+1.007 (10)	+2.37 (16)	Be71
			-1.236 (2) ^a	+0.592 (6)	0.9995 (2) ^a	2.35 (16)	Co71
			-1.233 (6) ^a	+0.591 (7)	0.995 (9)	2.34 (16)	Go71a
			1.241 (4) ^a	0.594 (6)			No71a
			1.2365 (10) ^a	0.592 (6)	1.0015 (10) ^a	2.35 (16)	Bo74a
			-1.2368 (8) ^b	+0.592 (6) ^b	+0.9996 (4) ^b	+2.34 (16) ^b	
	43.8	7/2	+0.293 (10)	-0.140 (5)	0.21 (5)	0.49 (12)	Sy71, Sy73
	74.6	3/2	3.5	≈ 1.7			Sk61
			+0.84 (5)	-0.402 (24)	+0.48 (4)	+1.13 (12)	Bo67
			+0.852 (12) ^a	-0.408 (7)	+0.60 (5) ^a	+1.41 (15)	He67, He68
			+0.840 (24) ^a	-0.402 (12)	+0.56 (4) ^a	+1.32 (13)	Cr68
			+0.828 (15) ^a	-0.396 (7)	0.58 (4) ^a	1.36 (10)	Kh68
			+0.840 (7) ^b	-0.403 (6) ^b	+0.577 (25) ^b	+1.36 (11) ^b	
¹⁶² Dy	80.7	2		+0.74 (8) ^g			He67a, He68
¹⁶⁴ Dy	73.4	2	r12	+0.68 (3) ^a	r13	-1.95 (21)	Mu66a, Mu68
				+0.71 (5) ^{a,g}			OI68
				0.69 (3) ^b			
¹⁶⁵ Ho	0	7/2		+4.12 (4)			(Ha72)
	94.7	9/2	0.99 (4)	4.08 (16)			Ge72
¹⁶⁴ Er	91.5	2	r14	0.694 (15)			Mu68
¹⁶⁶ Er	80.6	2		~ 0.5 ^g			Ki62

Table 1. Nuclear moment data from Mössbauer spectroscopy--continued.

Isotope	Energy	Spin	R_u	μ	R_Q	Q	Reference
^{166}Er	80.6	2		$\pm 0.61(3)^{\text{a,g}}$		$-1.60(16)^{\text{a,g,u}}$	Co64b
			r 15	0.624(15) ^a			Do64
						-1.5(5) ^{a,g,u}	Hu65a
				0.640(16) ^{a,g}			Mu68
				0.629(10) ^b		-1.59(15) ^{b,u}	
^{168}Er	79.8	2		0.66(4) ^{a,g}			St67
			r 16	0.655(14) ^a			Mu66b, Mu68
				0.656(13) ^b			
^{170}Fr	79.3	2	r 17	0.630(13)	r 18	1.67(30) ^u	Wi68a, Wi69
^{159}Tm	0	1/2		-0.2310(15)			(Gi67)
	8.4	3/2				-1.1(1) ^{a,g}	Hu63
			-2.33(4) ^a	+0.538(10)		-1.09(5) ^{g,u}	Ka63
			-3.2(7)	+0.75(15)			No63
			-2.17(10) ^a	+0.501(23)		-1.3(1) ^{a,g}	Co64a
			-2.40(7) ^{a,d}	+0.554(17)		-1.5 ^{a,g}	Ki64
			-2.22(7) ^a	+0.513(16)			Co68
			-2.31(4) ^b	+0.534(10) ^b		-1.21(8) ^b	
^{170}Yb	84.3	2				-2.14 ^u	(El60)
				0.668(10) ^{a,g}			Hu65
				0.66(4) ^{a,g}			Ec67a
				0.670(12) ^{a,g}			Mu68
				0.669(8) ^b			
^{171}Yb	0	1/2		+0.49188(20)			(Cl72)
	66.7	3/2			r 19	-1.56 ^{a,u}	Ka65
			0.716(6) ^{a,d}	0.3520(3)	r 19	-1.61 ^{a,u}	Gu66
			0.706(5) ^a	0.3475(22)			He66
					r 19	-1.61 ^{a,u}	Pi71
			0.710(5) ^b	0.349(2) ^b		-1.59(3) ^{b,u}	
	75.9	5/2			r 20	-2.24 ^{a,u}	Ka66
			2.055(10)	1.011(5)	r 21	-2.18 ^{a,u}	He67, He70
						-2.21(4) ^{b,u}	Pi71

Table 1. Nuclear moment data from Mössbauer spectroscopy--continued.

Isotope	Energy	Spin	R_{II}	μ	R_Q	Q	Reference
^{172}Yb	78.7	2		0.670 (20) ^g			Mu66
			r23	0.663 (13)	r22	-2.16 ^{a,u}	Ec67
				0.664 (8) ^c		-2.18 ^{a,u} -2.17(4) ^{b,u}	Mu68 Mu68 Pi71
^{174}Yb	76.5	2			r24	-2.22 ^u	Ec67c, Ec67
				0.676 (30) ^{a,g}			Ec67a
			r25	0.673 (12)			Mu66 Mu66c
				0.670 (6) ^{a,g}	r24	-2.14 ^{a,u}	Mu68
				0.676 (8) ^{a,g}		-2.14 ^{a,u}	He71
				0.672 (5) ^b		-2.14 (4) ^{b,u}	Pi71
^{176}Yb	82.1	2	1	0.76 (4) ^g	r26	-2.24 ^u	Ec67
^{176}Hf	88.4	2				-2.08 ^u	Ec67b, Ec67a
^{178}Hf	93.2	2			r27	-1.89 ^{a,u}	(Ha61)
						-2.00 ^{a,u}	Ge68
^{180}Hf	93.3	2			r28	-1.94 (6) ^{b,u}	
						-2.02 ^{a,u}	Ge66, Ge68
						-1.98 ^{a,u}	Sn68
					r29	-1.91 ^{a,u}	Sn68
					r28	-1.98 ^{a,u}	Ch70
					r29	-1.88 ^{a,u}	Ch70
					r29	-1.85 ^{a,u}	Bo73
					r29	-1.84 ^{a,u}	Zi73
			r30			-1.92 (2) ^{b,u}	Ko71
^{181}Ta	0	7/2		+2.35 (1)			(Er73)
						+3.9 (4) ^u	(Mu57)
			6.2	+2.19 (6) ^a	+5.16 (15)	+0.74 (30)	+2.9 (3) ^u
				+2.25 (4) ^a	+5.29 (10)		Sa68 Ka70a

Table 1. Nuclear moment data from Mössbauer spectroscopy--continued.

Isotope	Energy	Spin	R_u	u	R_Q	Q	Reference
^{181}Ta	6.2	9/2			+1.133 (10) ^c	+ 4.4 (5) ^{c,u}	Sa72, Ka72, Ka73
				+2.23 (3) ^b	+5.24 (7) ^b		
^{180}W	103.0	2			r31	-1.87 ^{a,u}	He72
					r31	-1.78 ^{a,u}	Zi73
						-1.82 (4) ^{b,u}	
^{182}W	100.1	2				-1.81 ^u	(Ho61)
				0.47 (5) ^{a,e}			Ch65
				0.532 (18) ^{a,g}			Pe68b
				0.44 (4) ^{a,g}			Fr67, Fr69
^{183}W	46.5	3/2		0.512 (25) ^b	r32	-1.5	Sh66
				-0.1 (1) ^g			Ag67
	99.1	5/2	r33	0.90 (5) ^a	r34	-1.70 ^{a,u}	Ag67
				0.930 (43) ^{a,g}	r34	-1.56 ^{a,u}	Pe68a
				0.92 (3) ^b		-1.63 (7) ^{b,u}	Ge74
^{184}W	111.2	2			r35	> 1.36 ^u	Ph62
				0.50 (6) ^{a,e}			Ch65
				0.59 (2) ^{a,g}	r35	-1.70 ^{a,u}	Pe67, Pe68a, Pe68b
					r35	-1.68 ^{a,u}	Ch69a
					r35	-1.75 ^{a,u}	Ob71
					r35	-1.73 ^{a,u}	Ge74
			r36	0.57 (3) ^a			Pe68a, Pe68b
				0.578 (17) ^b		-1.72 (3) ^{b,u}	
^{186}W	122.5	2		0.68 (6) ^{a,e}			Ch65
			r37	0.60 (3) ^a			Pe67, Pe68a Pe68b
				0.624 (22) ^{a,g}	r38	-1.60 ^{a,u}	Pe67, Pe68a Pe68b
					r38	-1.64 ^{a,u}	Ch69a
					r38	-1.64 ^{a,u}	Ob71
				0.621 (17) ^b		-1.73 ^{a,u}	Ge74
						-1.65 (3) ^{b,u}	

Table 1. Nuclear moment data from Mössbauer spectroscopy--continued.

Isotope	Energy	Spin	R_u	μ	R_Q	Q	Reference
^{186}Os	137.2	2		0.64 (3) ^{a,e}		-1.50 (10) ^u	Ch65
				0.562 (16) ^{a,g}			
				0.58 (3) ^b			Wa70, Wa72
^{188}Os	155.0	2	r 39	0.62 (5) ^{a,e}	r 40	-1.36 (9) ^u	Ch65
				0.63 (4) ^a			Wa70, Wa72
^{189}Os	0	3/2		0.63 (3) ^b		+ 0.6565 (3)	(Sc68)
				+ 0.6565 (3)			
					r 41	0.8 (2) ^u	
						0.94 (7) ^{f,u}	Wa72
	36.3	1/2	0.34 (4)	0.23 (3)			Wa69
	69.6	5/2	1.508 (15) ^a	0.990 (10)			Pe68c
			1.47 (3)	0.965 (20)			Gr69a
			1.488 (22) ^a	0.977 (14)	-0.735 (12)	-0.6 (2) ^u	Ku68, Wa72
			1.502 (12) ^b	0.986 (8) ^b			
^{190}Os	187.0	2			r 42	-1.17 (11) ^u	Wa72
^{191}Ir	0	3/2		+ 0.1453 (6)		+ 0.78 (20) ^u	(Na68)
				+ 0.1453 (6)			
							Bu73
							Wa67a, Wa68
^{193}Ir	82.4	1/2	+3.71 (3) ^c	+0.540 (5) ^c		+0.515 (25)	Ow69
			+3.55 (17) ^d	+0.515 (25)			
				3.00 (58) ^e			Da68
^{193}Ir	129.5	5/2		+3.8 (8) ^{d,c}	+0.55 (5) ^c		Ow69
				+3.8 (8) ^{d,c}	+0.55 (5) ^c		(Na68)
				+ 0.1583 (6)		+ 0.70 (18) ^u	Bu73
^{195}Pt	73.1	1/2	3.0 (1)	0.47		At67a	Wa67, Wa67a Wa68
			2.958 (6) ^c	0.4683 (20) ^c			
				3.015 (13)	0.4772 (27)		Pe69
				+ 0.6060 (3)			(Pr51)
^{195}Pt	98.8	3/2		-0.8 (1)			Be65
				-0.65 (15)			At66
			-1.01 (8) ^{c,d}	-0.61 (5) ^c			Ag67a
				-0.60 (15)			Bu67

Table 1. Nuclear moment data from Mössbauer spectroscopy--continued.

Isotope	Energy	Spin	R_u	u	R_Q	Q	Reference
^{195}Pt	129.8	5/2	1.35(30) ^a	0.82(2) ^a			Wa71
				0.88(11) ^{a,g}			Wo72
				0.90(8) ^{a,g}			Ru71, Ru74
				0.854(19) ^b			
^{197}Au	0	3/2		+ 0.1448(7)			(Da67)
				+ 0.37(4)			Gr64b
			2.89(3) ^{a,d}	0.419(5)			Co68a
			2.864(28) ^{a,d}	0.415(4)			Ro63, Se65, Pa67a Bu68, Th68, Pa70
			2.875(22) ^b	0.416(3) ^b			
^{234}U	43.5	2			- 2.89(4) ^u		(Fo71)
^{236}U	45.2	2			r44	- 2.86(15) ^{a,u}	Mo72, Mo74
			r45		r44	- 3.27(26) ^{a,u}	Me72, Me74
						- 2.96(18) ^{b,u}	
^{238}U	44.9	2				- 3.0	Ru69
					r46	- 3.21(21) ^{a,u}	Mo72, Mo74
			r47		r46	- 3.27(29) ^{a,u}	Me72, Me74
						- 3.23(17) ^{b,u}	
^{237}Np	0	5/2		+ 2.5(3)			(Hu60, E165, Le70)
						+ 4.1(7) ^f	Du69
			59.5	+ 0.537(5) ^a	+ 1.34(12)	+ 0.99(1) ^c	+ 4.1(7) ^{c,u}
				+ 0.533(5) ^b	+ 1.33(12)	+ 1.0(1)	+ 4.1 ^u
^{243}Am	0	5/2		+ 0.535(4) ^b	+ 1.34(12) ^b		Du68a, Du68
						+ 4.9 ^u	(Ma56)
			84.0	5/2		+ 0.962(15)	+ 4.7 ^u
							Me73

^aValue selected to be included in averaging procedure.

^bAverage of selected values, used as adopted value for the ratio or moment.

^cValue selected as adopted value.

^dMoment ratio calculated from the excited state and the ground state moments or appropriate splittings quoted in the reference.

^eObtained from a measurement of the angular distribution of resonant scattering.

^fGround state moment determined by Mössbauer spectroscopy.

^gMoment derived assuming a known magnetic hyperfine field or electric field gradient which was obtained from other measurements or by calculation.

^hData inadequate to decide between two possibilities.

^uUncorrected for the Sternheimer effect.

Explanation of Table 2**Number**

The number cross-references an entry in table 1. There the ratio value is combined with an adopted value for one of the moments to calculate the other moment.

Ratio

Moments are specified by the isotope and energy of the level in question. Thus $Q(^{57}\text{Fe}, 14.4)$ is the quadrupole moment of the 14.4 keV level in ^{57}Fe .

Explanation of Table 3

Values for ratios and moments obtained either by direct selection or averaging are summarized from table 1. Notations and conventions are the same as in table 1. A listed R_μ or R_Q indicates the ratio of the moment for the indicated state to that of the ground state of the same isotope. Only results determined by Mössbauer spectroscopy are listed. Quadrupole moments marked with superscripts are uncorrected for Sternheimer corrections.

Table 2. Miscellaneous nuclear moment ratios from Mössbauer spectroscopy

Number	Ratio	Value	Reference
r1	$Q(^{99}\text{Ru}, 89.4)/Q(^{57}\text{Fe}, 14.4)$	1.70(4)	Ba72a
r2	$Q(^{119}\text{Sn}, 23.83)/Q(^{121}\text{Sb}, 0)$	0.22(7)	Mi72
r3	$Q(^{119}\text{Sn}, 89.5)/Q(^{119}\text{Sn}, 23.8)$	2.2(2)	Be72
r4	$Q(^{125}\text{Te}, 35.5)/Q(^{127}\text{I}, 0)$	0.30	Pa67
r5	$Q(^{129}\text{Xe}, 39.58)/Q(^{131}\text{Xe}, 0)$	3.45(9)	Pe64
r6	$Q(^{156}\text{Gd}, 88.98)/Q(^{155}\text{Gd}, 0)$	0.76(3)	St67
		1.19(8)	To68
		-1.51(2)	Ar74
r7	$Q(^{155}\text{Gd}, 0)/Q(^{157}\text{Gd}, 0)$	0.78(6)	Pr68
r8	$\mu(^{156}\text{Gd}, 87.5)/\mu(^{155}\text{Gd}, 0)$	-2.99(3)	Ar74
r9	$Q(^{158}\text{Gd}, 79.51)/Q(^{155}\text{Gd}, 0)$	0.82(2)	St67
r10	$Q(^{160}\text{Gd}, 75.3)/Q(^{155}\text{Gd}, 0)$	0.84(2)	St67
r11	$\mu(^{160}\text{Dy}, 86.79)/\mu(^{161}\text{Dy}, 0)$	2.0(2)	Co64
		1.62(10)	Of65
r12	$\mu(^{164}\text{Dy}, 73.39)/\mu(^{161}\text{Dy}, 0)$	-1.42(6)	Mu66a, Mu68
r13	$Q(^{164}\text{Dy}, 73.39)/Q(^{161}\text{Dy}, 0)$	-0.83(7)	Mu66a, Mu68
r14	$\mu(^{164}\text{Er}, 91.5)/\mu(^{166}\text{Er}, 80.56)$	1.103(15)	Mu67, Mu68
r15	$\mu(^{166}\text{Fr}, 80.56)/\mu(^{167}\text{Fr}, 0)$	1.94(5)	Do64
r16	$\mu(^{166}\text{Er}, 80.6)/\mu(^{168}\text{Er}, 79.8)$	0.960(13)	Mu68
r17	$\mu(^{170}\text{Er}, 79.3)/\mu(^{166}\text{Er}, 80.56)$	1.002(13)	Wi68a, Wi69
r18	$Q(^{170}\text{Er}, 79.3)/Q(^{166}\text{Er}, 80.56)$	1.05(16)	Wi68a, Wi69
r19	$Q(^{171}\text{Yb}, 66.74)/Q(^{170}\text{Yb}, 84.26)$	0.73	Ka65
		0.75	Gu66
		0.752(16)	Pl71
r20	$Q(^{171}\text{Yb}, 75.89)/Q(^{171}\text{Yb}, 66.74)$	1.41(5)	Ka66
r21	$Q(^{171}\text{Yb}, 75.89)/Q(^{170}\text{Yb}, 84.26)$	1.020(27)	Pl71
r22	$Q(^{172}\text{Yb}, 78.67)/Q(^{170}\text{Yb}, 84.26)$	1.01(2)	Ec67
		1.020(12)	Pl71
r23	$\mu(^{172}\text{Yb}, 78.67)/\mu(^{170}\text{Yb}, 84.26)$	0.991(15)	Mu68

Table 2. Miscellaneous nuclear moment ratios from Mössbauer spectroscopy--continued.

Number	Ratio	Value	Reference
r24	$Q(^{174}\text{Yb}, 76.5)/Q(^{170}\text{Yb}, 84.26)$	1.04 (2)	Ec67c, Ec67
		1.001 (21)	He71
		1.000 (19)	Pl71
r25	$\mu(^{170}\text{Yb}, 84.26)/\mu(^{174}\text{Yb}, 76.5)$	0.994 (13)	Mu66c, Mu68
r26	$Q(^{176}\text{Yb}, 82.1)/Q(^{170}\text{Yb}, 84.26)$	1.045 (20)	Ec67
r27	$Q(^{176}\text{Hf}, 88.36)/Q(^{178}\text{Hf}, 93.17)$	1.10 (2)	Ge68
		1.040 (8)	Sn68
		1.03 (2)	Ge66, Ge68
r28	$Q(^{176}\text{Hf}, 88.36)/Q(^{180}\text{Hf}, 93.33)$	1.053 (15)	Sn68
		1.05 (2)	Ch70
		1.014 (13)	Sn68
r29	$Q(^{178}\text{Hf}, 93.17)/Q(^{180}\text{Hf}, 93.33)$	1.03 (2)	Ch70
		1.05 (3)	Bo73
		1.052 (21)	Zi73
r30	$\mu(^{180}\text{Hf}, 93.33)/\mu(^{178}\text{Hf}, 93.17)$	0.96 (2)	Ko71
r31	$Q(^{180}\text{W}, 103)/Q(^{182}\text{W}, 100.1)$	1.03 (4)	He72
		0.983 (22)	Zi73
		0.83 (14)	Sh66
r32	$Q(^{183}\text{W}, 46.48)/Q(^{182}\text{W}, 100.1)$	1.75 (5)	Ag67
		0.94 (4)	Ag67
r33	$Q(^{183}\text{W}, 99.1)/Q(^{182}\text{W}, 100.1)$	0.86 (6)	Ge73
		> 0.75	Ph62
r35	$Q(^{184}\text{W}, 111.2)/Q(^{182}\text{W}, 100.1)$	0.938 (15)	Pe67, Pe68a, Pe68b
		0.930 (16)	Ch69a
		0.965 (8)	Ob71
		0.955 (3)	Ge73
		1.11 (2)	Pe68a, Pe68b
r36	$\mu(^{184}\text{W}, 111.2)/\mu(^{182}\text{W}, 100.1)$	1.18 (3)	Pe67, Pe68a, Pe68b
		0.882 (17)	Pe67, Pe68a, Pe68b
r37	$\mu(^{186}\text{W}, 122.5)/\mu(^{182}\text{W}, 100.1)$	0.908 (24)	Ch69a
		0.906 (18)	Ob71
		1.08 (5)	Wa70
r39	$\mu(^{188}\text{Os}, 155.03)/(\mu(^{186}\text{Os}, 137.16)$		

Table 2. Miscellaneous nuclear moment ratios from Mössbauer spectroscopy--continued.

Number	Ratio	Value	Reference
r40	$Q(^{188}\text{Os}, 155.03)/Q(^{186}\text{Os}, 137.16)$	+ 0.909 (17)	Wa70, Wa72
r41	$Q(^{189}\text{Os}, 0)/Q(^{188}\text{Os}, 155.03)$	- 0.586 (11)	Wa72
r42	$Q(^{190}\text{Os}, 187)/Q(^{188}\text{Os}, 155.03)$	+ 0.863 (51)	Wa72
r43	$Q(^{191}\text{Ir}, 0)/Q(^{193}\text{Ir}, 0)$	1.03 (3)	Wa67, Wa68a
r44	$Q(^{236}\text{U}, 43.5)/Q(^{234}\text{U}, 45.3)$	0.99 (5)	Mo72, Mo74
		1.13 (9)	Me72, Me74
r45	$\mu(^{236}\text{U}, 43.5)/\mu(^{234}\text{U}, 45.3)$	0.98 (6)	Me72, Me74
r46	$Q(^{238}\text{U}, 44.7)/Q(^{234}\text{U}, 45.3)$	1.11 (7)	Mo72, Mo74
		1.13 (10)	Me72, Me74
r47	$\mu(^{238}\text{U}, 44.7)/\mu(^{234}\text{U}, 45.3)$	0.94 (9)	Me72, Me74

Table 3. Summary of adopted values

Isotope	Energy	Spin	R_μ	μ	R_Q	Q
^{57}Fe	14.4	3/2	-1.7142 (4)	-0.15532 (4)		+0.209 (5)
^{61}Ni	67.4	5/2	-0.637 (11)	+0.478 (7)	-1.21 (13)	-0.20 (3)
^{67}Zn	93.3	1/2	+0.66 (3)	+0.58 (3)		
^{83}Kr	9.4	7/2	+0.971 (2)	-0.943 (2)	1.70 (2)	+0.430 (3) ^U
^{99}Ru	89.3	3/2	0.456 (2)	-0.285 (5)	+2.88 (4)	0.3 (7) ^U
^{99}Tc	140.5	7/2	+0.64 (16)	+3.6 (8)		
^{119}Sn	23.8	3/2	-0.605 (17)	+0.633 (18)		-0.065 (5) ^U
	89.0	11/2		1.40 (8)		-0.14 (1) ^U
^{121}Sb	0	5/2				-0.28 (6) ^U
	37.2	7/2	0.735 (9)	+2.47 (3)	1.34 (1)	-0.38 (8) ^U
^{125}Te	35.5	3/2	-0.69 (6)	+0.61 (5)		-0.200 (23) ^U
^{127}I	57.6	7/2	0.905 (16)	2.54 (4)	-0.896 (2)	-0.71 (9) ^U
^{129}I	27.8	5/2	1.0687 (11)	+2.797 (3)	+1.2380 (15)	-0.68 (6) ^U
^{129}Xe	39.6	3/2	-0.75 (12)	+0.58 (9)		-0.41 (4)
^{133}Cs	81.0	5/2	+1.335 (8)	+3.443 (21)		
^{141}Pr	145.2	7/2	+0.69(2)	+2.87 (9)		
^{145}Nd	72.5	5/2	+0.489 (4)	-0.320 (3)		
^{147}Pm	91.0	5/2	1.373 (2)	3.60 (5)	0.8 (4)	0.6 (3) ^U
^{147}Sm	122.1	5/2	+0.551 (31)	-0.448 (25)	+1.7 (7)	-0.31 (12) ^U
^{149}Sm	0	7/2				0.060 (15) ^U
	22.5	5/2	+0.929 (1)	-0.623 (6)	8.3 (21)	0.50 (1) ^U
^{152}Sm	121.8	2		0.84 (5)		
^{154}Sm	81.9	2		0.78 (4)		-1.3 (5)
^{151}Eu	21.6	7/2	0.7465 (6)	2.5865 (26)	1.312 (19)	+1.50 (7) ^U
^{153}Eu	83.4	7/2	+1.18 (4)	+1.80 (6)		
	97.4	5/2	+2.10 (15)	+3.21 (23)		
	103.2	3/2	+1.336 (3)	2.043 (5)	0.520 (3)	1.51 (6) ^U
^{155}Gd	86.5	5/2	+2.049 (20)	-0.529 (5)	0.14 (5)	0.22 (8) ^U
	105.3	3/2	-0.55 (5) or +1.80 (18)	+0.14 (4) or -0.47 (7)	0.90 (3)	1.57 (16) ^U
^{156}Gd	88.9	2		0.778 (7)		-2.40 (24)

Table 3. Summary of adopted values--continued.

Isotope	Energy	Spin	R_{μ}	μ	R_Q	Q
^{157}Gd	0	3/2				$2.00(26)^{\text{u}}$
	64.0	5/2	+ 1.515 (7)	0.5133 (26)	1.79 (2)	$3.6(5)^{\text{u}}$
^{158}Gd	79.5	2		0.77 (4)		$1.30(14)$
^{160}Gd	75.3	2				$1.34(14)$
^{159}Tb	58.0	5/2	0.80(5) or 1.15(5)	+ 1.60 (10) or + 2.29 (10)		
^{160}Dy	86.8	2		0.77(4)		
^{161}Dy	25.6	5/2	- 1.2368 (18)	+ 0.592 (6)	+ 0.9996 (4)	+ 2.34 (16)
	43.8	7/2	+ 0.293 (10)	- 0.140 (5)	0.21 (5)	$0.49(12)$
	74.6	3/2	+ 0.840 (7)	- 0.403 (6)	+ 0.59 (3)	+ 1.36 (11)
^{162}Dy	80.7	2		+ 0.74 (8)		
^{164}Dy	73.4	2		0.69 (3)		$-1.95(21)$
^{165}Ho	94.7	9/2	0.99 (4)	4.08 (16)		
^{164}Er	91.5	2		0.694 (15)		
^{166}Er	80.6	2		0.629 (10)		$-1.59(15)^{\text{u}}$
^{168}Er	79.8	2		0.656 (13)		
^{170}Er	79.3	2		0.630 (13)		$-1.67(30)^{\text{u}}$
^{169}Tm	8.4	3/2	- 2.31(4)	+ 0.534 (10)		$-1.21(8)$
^{170}Yb	84.3	2		0.669 (8)		
^{171}Yb	66.7	3/2	0.710 (5)	0.349 (2)		$-1.59(3)^{\text{u}}$
	75.9	5/2	2.055 (10)	1.011 (5)		$-2.21(4)^{\text{u}}$
^{172}Yb	78.7	2		0.664 (8)		$-2.17(4)^{\text{u}}$
^{174}Yb	76.5	2		0.672 (5)		$-2.14(4)^{\text{u}}$
^{176}Yb	82.1	2		0.76 (4)		-2.24^{u}
^{176}Hf	88.4	2				-2.08^{u}
^{178}Hf	93.2	2				$-1.94(4)^{\text{u}}$
^{180}Hf	93.3	2				$-1.92(2)^{\text{u}}$
^{181}Ta	6.2	9/2	+ 2.23 (3)	+ 5.24 (7)	+ 1.133 (10)	+ 4.4 (5) ^u
^{180}W	103.0	2				$-1.82(4)^{\text{u}}$
^{182}W	100.1	2		0.512 (25)		
^{183}W	46.5	3/2		- 0.1 (1)		-1.5
	99.1	5/2		0.92 (3)		$-1.63(7)^{\text{u}}$

Table 3. Summary of adopted values--continued.

Isotope	Energy	Spin	R_{μ}	μ	R_Q	Q
^{184}W	111.2	2		0.58 (2)		-1.72 (3) ^u
^{186}W	122.5	2		0.62 (2)		-1.65 (3) ^u
^{186}Os	137.2	2		0.58 (3)		-1.50 (10) ^u
^{188}Os	155.0	2		0.63 (3)		-1.36 (9) ^u
^{189}Os	0	3/2				0.94 (7) ^u
	36.3	1/2	0.34 (4)	0.23 (3)		
	69.6	5/2	1.502 (12)	0.986 (8)	-0.735 (12)	-0.6 (2) ^u
^{190}Os	187.0	2				-1.17 (11) ^u
^{191}Ir	0	3/2				+0.78 (20) ^u
	82.4	1/2	+3.71 (3)	+0.540 (5)		
	129.5	5/2	+3.8 (3)	+0.55 (5)		
^{193}Ir	73.1	1/2	2.958 (6)	0.4683 (20)		
^{195}Pt	98.8	3/2	-1.01 (8)	-0.61 (5)		
	129.8	5/2	1.35 (30)	0.854 (19)		
^{197}Au	77.3	1/2	2.875 (22)	0.416 (3)		
^{236}U	45.2	2				-2.95 (14) ^u
^{238}U	44.9	2				-3.23 (17) ^u
^{237}Np	0	5/2				+4.1 (7) ^u
	59.5	5/2	+0.535 (4)	+1.34 (12)	0.99 (1)	+4.1 (7) ^u
^{243}Am	84.0	5/2			+0.962 (15)	+4.7 ^u

^uUncorrected for the Sternheimer effect.

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