

# Nuclear Spins and Moments

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A summary of nuclear-moment values and an index, arranged by  $Z$  and  $A$ , is presented. The summary value is based on the experimentally determined values of the nuclear moments which have been listed in tables according to the techniques used. Each table is preceded by a short introduction describing the experimental technique involved and the method of calculating the moment from the measured quantities. References are given for all data quoted. The date for the last systematic literature search is included with each table. This tabulation supplements and revises the earlier tables which appeared in Nuclear Data Tables, Volume A5, 433-612 (1969).

**Key words:** Evaluated data; nuclear electric hexadecapole moments; nuclear electric quadrupole moments; nuclear magnetic dipole moments; nuclear magnetic octupole moments; nuclear spins.

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## I. General Introduction

Measured values of nuclear moments, and of some of the auxiliary constants from which moment values are derived, are listed in this compilation. Since the auxiliary quantities determined by the various experimental techniques available today are quite different from each other, the experimental information is divided into eleven tables, each pertaining to a particular method or group of related methods. This division makes it possible to include information which is of interest to those concerned with a particular technique as well as values of the nuclear moments themselves.

Detailed descriptions of many of the methods have been presented by Ramsey [53Ra34]‡, Nierenberg [57Ni25], Kopfermann [58Ko90], Laukien [58La04], Townes [58To34], Cohen [59Co83], and by several authors in *Methods of Experimental Physics*, Volume 5, Nuclear Physics, Part B, edited by Yuan and Wu [63Yu02] and in *Hyperfine Interactions*, edited by Freeman and Frankel [67Fr15]. Brief introductions outlining the particular techniques are given with the individual tables.

In all tables, the values of the magnetic moments have been adjusted to a standard value of the magnetic moment of the proton by the compilers using the experimentally determined quantities and

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‡Alpha-numeric codes in brackets indicate literature references, the first two digits representing the year of publication, the letters representing the author.

adopted standard values of  $\mu_p$  and frequency ratios. An extensive discussion of the evaluation of the fundamental constants is given by Taylor, Parker, and Langenberg [69TaPa]. The most recent adjustment of the fundamental constants appears in Cohen and Taylor [73CoTa].

The Summary of Nuclear Moment Values and Index presents a list of the nuclear moments for all nuclei for which measurements have been made and serves as an index to the specific tables in which more detailed information will be found.

In preparation of the tables, all data available up to the cutoff date listed in each table were reviewed. Unless important for the determination of the sign of a moment, older values have been omitted when superseded by more accurate results.

The abbreviations used and policies adopted concerning signs, standards, uncertainties, standard values, and corrections are explained in tabular style on the following pages.

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The present compilation owes much to the earlier tabulations of J. Mack [50Ma50], H. E. Walchli [53Wa63], N. F. Ramsey [53Ra34], C. H. Townes [58To34], G. Laukien [58La04], I. Lindgren [65Li12], and V. S. Shirley [67Sh14].

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We would also like to thank Academic Press for permission to copy the table of diamagnetic correction factors from *Nuclear Moments* by H. Kopfermann [58Ko90], and W. R. Johnson for sending early drafts of his tables of diamagnetic correction factors for neutral atoms [72Jo18].

I would like to pay tribute to Dr. V. W. Cohen, my collaborator these many years, who died August 17, 1974. He was a man of very high principles, a good teacher and mentor. He was also a very warm, generous and direct person. He will be greatly missed — GHF.

## 2. Policies

Level Energies	Energies, given to identify the levels for which moment information is presented, are taken from the Nuclear Data Sheets (through Volume B5) or Table of Isotopes [67LeHo].
Half-lives	Half-lives which are given to identify the levels and which, in the case of Table J, are used to compute $\mu$ from values of $\omega\tau$ , have been taken from Marelius [68Ma49], Nuclear Data Sheets (through Volume B5), Table of Isotopes [67LeHo], or the author (in that order).
Signs	The sign of the nuclear moment given is that actually measured by the experimenter. When the sign cannot be determined, “±” appears before the value.
Uncertainties	Uncertainties quoted for the measured quantities are those given by the experimenter. The uncertainty in the last figure of a number is printed in italics immediately after the number. For example, 0.745 25 means $0.745 \pm 0.025$ .
[ ]	Brackets enclose values of the nuclear spins for which there are no spectroscopic or resonance measurements but which are assumed in order to calculate magnetic moments from $g$ -values. They have also been used to indicate the model-dependent values of $Q$ , $\Omega$ , and $Q_4$ which are obtained by electron scattering.

( )

Parentheses enclose values measured by someone other than the author quoted.

**Zero-spin  
values**

Measured zero-spin values for even-even nuclei have been included in the tables. Experiments which gave rise to the now-accepted concept of zero spin for all even-even nuclei can be divided into two groups. The first group proves that the spins of several such nuclei are definitely zero by the absence of alternating intensities in the observed spectra of homonuclear diatomic molecules. The second group, which can only give an upper limit on the interaction constants when no hyperfine splitting is observed, indicates either that the spin is zero or that  $\mu$  (or  $Q$ ) is very small. The spin values of zero determined by this second group of experiments are marked by “♦” after the value.

**Standard  $\mu_p$**

$\mu_p = 2.792776 \text{ 3 l nm}$ . This result is obtained by averaging the values given by the experiments of [51Je10, 51So34, 55Co36, and 56Tr19] which yield  $\mu$  directly in nuclear magnetons. This leads to a value of  $\mu'_p$ , not corrected for atomic diamagnetism, of 2.79270 3 which has been used throughout in the calculation of moments measured relative to that of the proton in samples of water. The uncertainties in the calculated magnetic moments do not include any uncertainty in the value of  $\mu'_p$ .

**Conversion  
factors**

$$\gamma_p [\text{in rad} \cdot \text{s}^{-1} \cdot \text{T}^{-1}] \times (1.043953 \text{ 10}) \times 10^{-8} = \mu_p [\text{in nm}]$$

$$\mu_p [\text{in Bohr magnetons}] \times (1836.109 \text{ 11}) = \mu_p [\text{in nm}]$$

See [69TaPa].

**Standard  
frequency  
ratios**

Standard frequency ratios,  $\nu(A)/\nu_p$ , which were used to calculate values of the magnetic moments from relative measurements, are given below. With the exception of the optical pumping (OP) measurement for  $^{199}\text{Hg}$ , these ratios were determined by nuclear magnetic resonance (NMR).

$^2\text{H}$	0.15350609† 2	$^{45}\text{Sc}$	0.24291623 10
$^7\text{Li}$	0.38863618† 8	$^{50}\text{V}$	0.0997015‡ 10
$^{11}\text{B}$	0.3208377‡ 2	$^{55}\text{Mn}$	0.24789167 6
$^{14}\text{N}$	0.07226261 1	$^{73}\text{Ge}$	0.03488401 14
$^{23}\text{Na}$	0.26451775† 7	$^{85}\text{Rb}$	0.096552095‡ 54
$^{27}\text{Al}$	0.26056752 7	$^{127}\text{I}$	0.200080‡ 14
$^{35}\text{Cl}$	0.09797858 5	$^{199}\text{Hg}$	0.178788 15 (NMR)
$^{39}\text{K}$	0.0466636‡ 7		0.1782706 3 (OP)
$^{41}\text{K}$	0.02561295 12		

†From a least squares adjustment of the  $g$ -factors for  $^2\text{H}$ ,  $^7\text{Li}$ , and  $^{23}\text{Na}$  with  $g_p = 5.58540$  fixed.

‡Weighted average.

**Diamagnetic  
corrections**

All magnetic moments are given with the diamagnetic correction,  $\sigma$ , applied. To obtain the corrected  $g$ - or  $\mu$ -value, the uncorrected value was multiplied by the factor,  $(1-\sigma)^{-1}_{DK}$ , listed in the table below for that element. These values, which are taken from Kopfermann [58Ko90] p450, are based on calculations of Dickinson [50Di10]. The uncertainty in the value of the added correction is assumed to be 5%. New calculations, using Hartree-Fock relativistic electron wave functions, show that the earlier values of  $\sigma$  are too small. Diamagnetic correction factors for some closed shell and closed sub-shell ions can be found in Feiock and Johnson [68Fe05]. Average correction factors for neutral atoms have been calculated by Lin, Johnson and Feiock [72Jo18]. These values include the contribution of the closed-shell core of the atoms and an average shielding factor for the valence electrons in the ground state configuration. This average is made over the ground state multiplet assigning statistical weights to the subshells. The diamagnetic correction factors do not include possible large contributions for individual valence electrons. In view of these better, unpublished values, which were received after most of the moments had been reevaluated, values of  $(1-\sigma)^{-1}_{LJF}$  based on the average neutral-atom diamagnetic correction factors of Lin, Johnson and Feiock [72Jo18] are included in the table below.

Table of Diamagnetic Correction Factors

$(1-\sigma)_{DK}^{-1}$	$(1-\sigma)_{LJF}^{-1}$	$(1-\sigma)_{DK}^{-1}$	$(1-\sigma)_{LJF}^{-1}$	$(1-\sigma)_{DK}^{-1}$	$(1-\sigma)_{LJF}^{-1}$	$(1-\sigma)_{DK}^{-1}$	$(1-\sigma)_{LJF}^{-1}$
$_1H$	1.0000278†	1.00001775†	$^{25}Mn$	1.00191	1.002077	$^{49}In$	1.00493
$^2He$	1.000060	1.00005994	$^{26}Fe$	1.00202	1.002203	$^{50}Sn$	1.00506
$^3Li$	1.000101	1.0001048	$^{27}Co$	1.00214	1.002332	$^{51}Sb$	1.00520
$^4Be$	1.000149	1.0001531	$^{28}Ni$	1.00226	1.002468	$^{52}Te$	1.00534
$^5B$	1.000199	1.0002068	$^{29}Cu$	1.00238	1.002611	$^{53}I$	1.00548
$^6C$	1.000261	1.0002672	$^{30}Zn$	1.00250	1.002749	$^{54}Xe$	1.00562
$^7N$	1.000325	1.0003332	$^{31}Ga$	1.00262	1.002888	$^{55}Cs$	1.00576
$^8O$	1.000395	1.0004059	$^{32}Ge$	1.00274	1.003031	$^{56}Ba$	1.00590
$^9F$	1.000464	1.0004844	$^{33}As$	1.00286	1.003177	$^{57}La$	1.00606
$^{10}Ne$	1.000547	1.0005693	$^{34}Se$	1.00297	1.003327	$^{58}Ce$	1.00620
$^{11}Na$	1.000629	1.0006495	$^{35}Br$	1.00309	1.003479	$^{59}Pr$	1.00635
$^{12}Mg$	1.000710	1.0007322	$^{36}Kr$	1.00322	1.003635	$^{60}Nd$	1.00651
$^{13}Al$	1.000795	1.0008172	$^{37}Rb$	1.00334	1.003790	$^{61}Pm$	1.00666
$^{14}Si$	1.000881	1.0009056	$^{38}Sr$	1.00346	1.003950	$^{62}Sm$	1.00683
$^{15}P$	1.000970	1.0009975	$^{39}Y$	1.00359	1.004114	$^{63}Eu$	1.00698
$^{16}S$	1.00106	1.001093	$^{40}Zr$	1.00372	1.004282	$^{64}Gd$	1.00714
$^{17}Cl$	1.00115	1.001191	$^{41}Nb$	1.00385	1.004456	$^{65}Tb$	1.00729
$^{18}A$	1.00124	1.001294	$^{42}Mo$	1.00398	1.004633	$^{66}Dy$	1.00746
$^{19}K$	1.00133	1.001394	$^{43}Tc$	1.00413	1.004815	$^{67}Ho$	1.00762
$^{20}Ca$	1.00142	1.001495	$^{44}Ru$	1.00427	1.005000	$^{68}Er$	1.00778
$^{21}Sc$	1.00151	1.001602	$^{45}Rh$	1.00440	1.005194	$^{69}Tm$	1.00794
$^{22}Ti$	1.00161	1.001716	$^{46}Pd$	1.00454	1.005389	$^{70}Yb$	1.00810
$^{23}V$	1.00171	1.001834	$^{47}Ag$	1.00467	1.005586	$^{71}Lu$	1.00827
$^{24}Cr$	1.00181	1.001956	$^{48}Cd$	1.00480	1.005789	$^{72}Hf$	1.00844
						$^{73}Ta$	1.00860
							1.01298

† For a spherical sample of water the factor is 1.0000260 [66My01]

‡ Value obtained by graphic extrapolation

Hyperfine-  
structure  
anomaly

Values of magnetic moments calculated from ratios of hyperfine-structure constants do not include a hyperfine-structure anomaly correction. This correction can range from zero to about 1% [70FuCo]. Some authors include a 1% uncertainty in the value of the magnetic moment to take account of this possible correction.

Q-values

The value of the quadrupole moment given is that quoted by the experimenter. The uncertainty may be as much as 50% or more because of the difficulties in estimating the electric field inhomogeneity at the nucleus, arising from the molecular and electronic environment, and the effect of the polarization of the electron core. Values marked by an asterisk, \*, indicate that the experimenter has made some Sternheimer or polarization corrections in computing the moment. For papers on Sternheimer corrections for specific atoms and ions, see [50St32, 51St93, 54Fo28, 54St11, 56St50, 57St39, 63St22, 66St23, 71St12, 71St44].

Compounds

In general, standard chemical notation is used with the exception of using an italicized number for the waters of crystallization and an italicized chemical symbol for an element which is replaced in a doped material. Some specific abbreviations have been used for the following compounds:

- CMN – cerium magnesium nitrate
- NES – neodymium ethyl sulphate
- $x$ IG –  $x$  iron garnet.

### 3. Abbreviations

A- ashta-,  $10^{+18}$ , an abbreviation of the Sanskrit for eighteen

ABMR atomic beam magnetic resonance

a- atto-,  $10^{-18}$

<i>a;A,B</i>	magnetic dipole interaction constant, given in MHz; $\text{cm}^{-1}$ respectively. See introduction to Table F, equation (2) for definition of <i>a</i> .
<i>B<sub>0</sub></i>	resonance magnetic field for stroboscopic observation of perturbed angular correlation
<i>b</i>	electric quadrupole interaction constant, given in MHz. See introduction to Table F, equation (3) for definition of <i>b</i> .
CEx	Coulomb excitation
CMN	cerium magnesium nitrate, $\text{Ce}_2\text{Mg}_3(\text{NO}_3)_{12} \cdot 24\text{H}_2\text{O}$
<i>c</i>	magnetic octupole interaction constant, given in MHz. See introduction to Table F, equation (4) for definition of <i>c</i> .
DR	optical double resonance
<i>d</i>	day
ENDOR	electron-nuclear double resonance
<i>eqQ</i>	electric quadrupole coupling constant Note: This quantity has the dimensions of energy. However, in microwave and radiofrequency experiments it is customary to refer to it in units of MHz and in atomic spectra experiments, in units of $\text{cm}^{-1}$ . To obtain proper energy units one should multiply the given values by <i>h</i> or <i>hc</i> , respectively.
<i>eq<sub>4</sub>Q<sub>4</sub></i>	electric hexadecapole interaction constant Note: This quantity, which is an energy difference, is expressed for convenience in units of MHz in radiofrequency experiments. It is understood that one must multiply the values given by <i>h</i> to convert to energy units.
<i>F</i>	total atomic angular momentum, $F=I+J$
<i>F</i>	Fermi, $10^{-13}\text{ cm}$
<i>f-</i>	femto-, $10^{-15}$
<i>G-</i>	giga-, $10^{+9}$
<i>G,G<sub>2</sub>,G<sub>4</sub></i>	angular correlation attenuation coefficients
<i>g</i> or <i>g<sub>I</sub></i>	nuclear <i>g</i> -factor, $\mu/I$
<i>g<sub>J</sub></i>	electronic <i>g</i> -factor of the atom, $\mu_J/J$
<i>g<sub>s</sub></i>	electronic spin <i>g</i> -factor
<i>gs</i>	ground state
<i>H</i>	magnetic field strength. In most of the tables <i>H</i> has been given in gauss. The SI (Système International) unit for the magnetic field, the tesla, corresponds to $10^4$ gauss
<i>H<sub>0</sub></i>	external or applied magnetic field
<i>H<sub>hf</sub></i>	hyperfine magnetic field
<i>H<sub>int</sub>, H<sub>eff</sub></i>	internal or effective magnetic field at the nucleus

$H_{\text{res}}$	magnetic field at resonance
h	hour
hfs	hyperfine structure
$I$	nuclear angular momentum or spin
$J-$	jitu-, $10^{+15}$ , from the Swahili for giant
$J$	total electronic angular momentum
$K$	Knight shift correction
$k-$	kilo-, $10^{+3}$
$k$	Boltzmann constant, $(1.38062 \cdot 6) \times 10^{-23} \text{ J}/\text{K}$ [69TaPa]
LX	level crossing
$M-$	mega-, $10^{+6}$
$M_{22}$	quadrupole matrix element for the $2+$ state, $\langle 2+    \text{ME2}    2+ \rangle$
$m-$	milli-, $10^{-3}$
m	minute
$m_I, m_J$	magnetic quantum number, projection on $H$ of $I$ and $J$ , respectively
NES	neodymium ethyl sulphate, $\text{Nd}(\text{C}_2\text{H}_5\text{SO}_4)_3 \cdot 9\text{H}_2\text{O}$
NMR	nuclear magnetic resonance
$n-$	nano-, $10^{-9}$
nm	nuclear magneton
OP	optical pumping
$P, P', P''$	electric quadrupole interaction constants, given in $\text{cm}^{-1}$ in paramagnetic resonance measurements
$p-$	pico-, $10^{-12}$
$Q$	nuclear electric quadrupole moment This quantity exists only for nuclei with $I \geq 1$ and is defined by
$eQ = \int \rho r^2 (3 \cos^2 \theta - 1) dV$	
where $\rho$ is the nuclear charge density, and $r$ and $\theta$ are the radial and polar coordinates of a volume element, $dV$ , referred to the nuclear center and axis of symmetry.	
$Q_0$	intrinsic quadrupole moment
$Q_{\text{rot}}$	rotational quadrupole moment

$Q_4$ 

nuclear electric hexadecapole moment

This quantity exists only for nuclei with  $I \geq 2$  and is defined by

$$eQ_4 = \int \rho r^4 (35 \cos^4 \theta - 30 \cos^2 \theta + 3) dV$$

where  $\rho$  is the nuclear charge density, and  $r$  and  $\theta$  are the radial and polar coordinates of a volume element,  $dV$ , referred to the nuclear center and axis of symmetry.

 $q$ 

$-\partial E_z / \partial z$ , the first derivative, evaluated at the nucleus, of the electric field along the axis of the molecule or atom

 $q_4$ 

$-\partial^3 E_z / \partial z^3$ , the third derivative, evaluated at the nucleus, of the electric field along the axis of the molecule or atom

SE

spin exchange

s

second

T-

tera-,  $10^{12}$ 

T

temperature

 $T_r$ 

repetition period for stroboscopic measurements

 $T_{1/2}$ 

half-life

 $t_{ave}$ 

mean time of observation

X

magnetic field attenuation coefficient, defined in terms of the  $G$ 's [62Go17]

xIG

 $x$  iron garnet,  $\text{Fe}_3x_2^{3+}(\text{SiO}_4)_3$ 

y

year

 $\beta$ paramagnetic correction factor,  $H = \beta H_0$  $\gamma_p$ gyromagnetic ratio of the proton,  $\gamma_p = \omega_{\text{Larmor}} / H = 4\pi\mu_p / h$  $\Delta, \Delta E$ energy splitting at low temperature,  $\Delta = g\mu_N H / k$  $\Delta\theta$ total angular shift for static and transient fields,  $\Delta\theta = \int_0^t \omega dt' = \omega\tau + \phi_i$  $\mu-$ micro-,  $10^{-6}$  $\mu$ 

nuclear magnetic dipole moment

This quantity exists only for nuclei with  $I \geq 1/2$  and is defined by

$$\mu = - \int r \cos\theta \text{ div } M \text{ d}V$$

where  $M$  is the total magnetic moment density due to the currents and spins in the nucleus, and  $r$  and  $\theta$  are the radial and polar coordinates of a volume element,  $dV$ , referred to the nuclear center and axis of symmetry.

 $\mu_B$ Bohr magneton,  $he/4\pi m_e c = (9.27410 \cdot 6) \times 10^{-24} \text{ J} \cdot \text{T}^{-1}$  [69TaPa] $\mu_B/\mu_N$ ratio of Bohr magneton to nuclear magneton,  $\mu_B/\mu_N = M_p/m_e = 1836.109 \cdot 11$  [69TaPa] $\mu_N$ nuclear magneton,  $he/4\pi M_p c = (5.05095 \cdot 5) \times 10^{-27} \text{ J} \cdot \text{T}^{-1}$  [69TaPa]

$\mu_J$	electronic magnetic moment
$\nu$	resonant frequency, $\Delta E/h$ ; $\omega/2\pi$
$\Delta\nu$	hyperfine-structure splitting This quantity in rf resonance literature is defined as $\Delta\nu=\Delta W/h$ in units of Hertz where $\Delta W$ is the energy separation between adjacent $F$ -states in the absence of an external field. In optical spectroscopy it is defined by $\Delta\nu=\Delta W/hc$ in $\text{cm}^{-1}$ (Kaysers).
$\sigma$	diamagnetic correction factor, see Policies.
$\tau$	mean life, $T_{1/2} = \tau \ln 2 = 0.693\tau$
$\tau_c$	collision life-time, $\tau_c = \text{mean free path}/\text{recoil velocity}$
$\phi_t$	total transient-field angular shift
$\Omega$	nuclear magnetic octupole moment This quantity exists only for nuclei with $I \geq 3/2$ and is defined by
	$\Omega = (1/2) \int r^3 (5\cos^3\theta - 3\cos\theta) \text{div} M \text{ d}V,$ where $M$ is the total magnetic moment density due to the currents and spins in the nucleus and $r$ and $\theta$ are the radial and polar coordinates of a volume element, $dV$ , referred to the nuclear center and axis of symmetry.
$\omega, \omega_{\text{Larmor}}$	Larmor angular precession frequency, $2\pi\mu H/hI$ or $2\pi gH\mu_N/h$
$\omega_q$	quadrupole resonance angular frequency, $\omega_q = [3/4I(2I-1)]\omega_Q$ for integer $I$ and $\omega_q = [3/2I(2I-1)]\omega_Q$ for half-integer $I$
$\omega_Q$	quadrupole interaction frequency, $\omega_Q = 2\pi eqQ/h$
$\omega_T$	angular shift of the angular correlation or distribution in the presence of a magnetic field
$\omega_p/\omega_{\text{cyc}}$	ratio of the nuclear magnetic resonance frequency of the proton to the cyclotron frequency of the proton This ratio is equal to the value of the magnetic moment of the proton in the nuclear magnetons.
$\omega_e/\omega_p$	ratio of the cyclotron frequency of a free electron to the nuclear magnetic resonance frequency of the proton The reciprocal of this ratio is equal to the value of the proton magnetic moment in Bohr magnetons.

#### 4. Summary of Nuclear Moment Values and Index

##### Introduction

In this table, a value is given for every nuclear moment for which a measured value has been tabulated in the separate tables. The index letter, under the column headed 'Index', indicates the table in which the measured moment values and auxiliary quantities will be found. Since the individual tables list data for a particular measuring technique, the

index also forms a code for the techniques by which moment information has been obtained.

In arriving at summary values of magnetic moments there has been no attempt to average all existing results since the spread of values is not always due to statistical fluctuations but often depends on the circumstances of the measurements. Certain techniques give more reliable results. These are listed below along with the major associated problems, enclosed in ( )'s.

ABMR by direct measurement, doublet separation, or triple resonance (configuration mixing)

**ENDOR** using materials for which the paramagnetic shielding is small (paramagnetic shielding)

**OP** (configuration mixing)

**NMR** using the most ionic materials or extrapolating to zero density or concentration (chemical shifts, Knight shifts for metals)

When the quoted experimental uncertainties and the differences between quoted values are of the same order of magnitude, a weighted average was made:

$$A = \frac{\sum_{i=1}^n e_i^{-2} (A_i)}{\sum_i e_i^{-2}},$$

where  $e_i$  is the quoted uncertainty in the quantity  $A_i$ . The uncertainty in the value  $A$  was then taken as the larger of the internal or external error:

$$e_{\text{internal}} = (\sum_i e_i^{-2})^{-1/2},$$

$$e_{\text{external}} = [(\sum_i e_i^{-2} (A_i - A)^2) / (n - 1) (\sum_i e_i^{-2})]^{1/2}.$$

The arithmetic average, with an uncertainty given by one standard deviation, was used when the quoted uncertainties in the individual measurements are smaller than ( $\approx$  or  $<$  1/10) the differences between the quoted values.

No attempt has been made to estimate uncertainties arising from chemical shifts or configuration mixing. Although these could be as large as 1%, most are of the order of 0.01% or less. No uncertainty is assumed for  $\mu_p$ . In the summary table the uncertainty is in the last significant figure.

The values quoted include the diamagnetic correction which is also tabulated.

For several nuclei the  $\mu$ -values obtained by two different methods are very consistent but large discrepancies exist between the two sets of values, for example between NMR and OP measurements. Both values are now listed and footnoted. For most purposes, an arithmetic average of the two values could be used. For relative NMR measurements, the NMR-value would give a better measure of the effective moment. (It is interesting to note that the discrepancy between the NMR and OP magnetic moment values for the II-B elements, Zn, Cd, Hg, varies almost linearly with  $Z$ .)

It is not simple to estimate the accuracy of a particular quadrupole moment because the value of a quadrupole moment derived from an interaction constant depends upon the assumptions made concerning the electronic configurations, the Sternheimer effect or polarization of the electron distribution by a nonspherical nuclear charge distribution (nuclear quadrupole moment), and the molecular binding. Uncertainties, arising from incomplete knowledge of the molecular binding, may be as large as 50%. Corrections for polarization effects can be of the order of 10–20%, although some have been calculated to be as large as 50%, for example for the 3d configuration of Sc. To obtain the summary value, an average of the data for a particular isotope of an element has been made. This average value is indicated by a superscript "s". The values of the quadrupole moment of the other isotopes of that element, marked by a superscript "r", were calculated using this average and the more accurately determined quadrupole moment ratios.

Magnetic octupole and electric hexadecapole moments have also been included in the summary list.

A few values of  $Q$ ,  $\Omega$ ,  $Q_4$  have been tabulated which have been derived from electron-scattering experiments. These are model-dependent and are indicated by brackets, [ ], surrounding the value.

#### Explanation of the Summary Table

**Nucleus** Chemical symbol with  $Z$ -,  $A$ -, and  $N$ -numbers

**Level** The energy of the nuclear level, in keV, given to identify the level for which nuclear moment information is presented

Values have been taken from the Nuclear Data Sheets (through B5), Table of Isotopes [67LeHo] or the experimenter's quoted value.

**$T_{1/2}$**  The half-life of the radioactive nucleus or excited level

Values have been taken from Marelius [68Ma49], Nuclear Data Sheets (through B5), Table of Isotopes [67LeHo] or the experimenter's value.

See Abbreviations for definitions of prefix-symbols used with units.

- I* Nuclear spin or angular momentum in units of  $h/2\pi$   
 Values enclosed in brackets, [ ], were not determined by spectroscopic or resonance measurements but were assumed in order to interpret data.
- $\mu$  Nuclear magnetic moments in nuclear magnetons, with diamagnetic correction  
 When ratios are given, the level-energy of the reference isotope, in keV, is indicated by a subscript.
- Diam. Corr. The diamagnetic correction which was added to the last significant figure of the uncorrected magnetic dipole moment to get the value quoted in the previous column  
 For example, for Li<sup>6</sup>,  $\mu = \mu_{\text{uncorrected}} + \text{Diam. corr.} = +0.82195 + 0.00008 = +0.82203$
- Q* Nuclear electric quadrupole moment in barns  
 Values marked by "s" are averages of the *Q*-values listed in the individual tables.  
 Those marked by "r" have been calculated by use of *Q*\* and measured *Q*-ratios.  
 Values marked by "\*" include polarization or Sternheimer corrections.  
 Values enclosed in brackets, [ ], are derived from electron-scattering experiments and are model-dependent.  
 When two values of *Q* are listed, the first refers to the value determined by Coulomb excitation reorientation assuming constructive interference and the second, destructive interference of the matrix elements.  
 When ratios are given, the level-energy of the reference isotope, in keV, is indicated by a subscript.
- $\Omega$  Nuclear magnetic octupole moment in nm-barns  
 Values enclosed in brackets, [ ], are derived from electron-scattering experiments and are model-dependent.
- Q*<sub>4</sub> Nuclear electric hexadecapole moment in barns<sup>2</sup>
- Index Directory to tables in which will be found the experimentally determined values on which the Summary Values are based.  
 Table A: Neutron, Proton, and Anti-Proton Moments  
 Table B: Nuclear Moments by Paramagnetic Resonance  
 Table C: Nuclear Moments by Microwave Spectroscopy  
 Table D: Nuclear Moments by Quadrupole Resonance  
 Table E: Nuclear Moments by Nuclear Magnetic Resonance  
 Table F: Nuclear Moments by Atomic and Molecular Beams  
 Table G: Nuclear Moments by Optical Spectroscopy  
 Table H: Nuclear Moments by Optical Double Resonance and Pumping Techniques  
 Table I: Nuclear Moments by Mössbauer Spectroscopy †  
 Table J: Nuclear Moments by Nuclear Orientation, Perturbed Angular Correlations, and Nuclear Specific Heat Measurements  
 Table K: Nuclear Moments by Coulomb Excitation Reorientation and Other Techniques

† For early data see [69FuCo]. See J. Stevens, J. Phys. Chem. Ref. Data 5, 1093 (1976), for recent data and evaluation.

## Summary of Nuclear Moment Values and Index

Nucleus	Level (keV)	$T_{1/2}$	$I$ ( $h/2\pi$ )	$\mu$ (nm)	Diam. Corr.	$Q$ (b)	$\Omega$ (nmb)	$Q_4$ ( $b^2$ )	Index
$^1_0 n_1$		12m	1/2	-1.91312					A
$^1_1 H_0$				-1.8					A
$^1_1 H_0$			1/2	+2.79278 <sup>j</sup>	8				A B F G H
$^2_1 H_1$			1	+0.85742	2	+0.0028			E F G H
$^3_1 H_2$		12y	1/2	+2.9789	1				E F G H
$^3_2 He_1$			1/2	-2.1276	1				E F G H
$^3_2 He_1^+$			1/2						F H
$^4_2 He_2$			0						G
$^6_2 He_4$		0.8s	0 <sup>d</sup>						F
$^6_3 Li_3$			1	+0.82203	8	-0.0008 <sup>r</sup>			E F H
$^6_3 Li_3^+$			1						H
$^7_3 Li_4$			3/2	+3.25636	33	-0.04 <sup>s</sup>	[+0.09]		E F G H K
$^8_3 Li_5$		0.8s	2	+1.6532	2				E H J
$^9_4 Be_5$			3/2	-1.17745	18	+0.05	[-0.04]		E F K
$^8_5 B_3$		770ms	[2]	$\pm 1.0355^p$	2				E J
$^{10}_5 B_5$			3	+1.8006	4	+0.085 <sup>r</sup>	[ $\pm 0.03$ ]		C D E F J K
$^{10}_5 B_5$	720	0.7ns	[1]	+0.6					J
$^{11}_5 B_6$			3/2	+2.6885	5	+0.041 <sup>s</sup>	[+0.08]		C D E F J K
$^{12}_5 B_7$		20.4ms	1	+1.0028 <sup>p</sup>		+0.018			E J
$^{13}_5 B_8$		19ms	[3/2]	$\pm 3.1771^p$		$\pm 0.05$			E J
$^{11}_6 C_5$		21m	3/2	(-?)0.99		(-?)0.031*			F
$^{12}_6 C_6$			0						G
$^{13}_6 C_7$			1/2	+0.7024	2				E F G
$^{14}_6 C_8$		5.6ky	0						G
$^{12}_7 N_5$		12ms	1	$\pm 0.457$					E J
$^{13}_7 N_6$		10m	1/2	$\pm 0.3221$	1				F
$^{14}_7 N_7$			1	+0.40375	13	+0.01			C E F G H J
$^{14}_7 N_7$	5830	12.4ps	[3]	$\pm 1.5$ to $2.6$					
$^{15}_7 N_8$			1/2	-0.2831	1				E F G H
$^{15}_8 O_7$		2.1m	1/2	$\pm 0.7189$	3				F
$^{16}_8 O_8$			0						G
$^{17}_8 O_9$			5/2	-1.8937	7	-0.026*			B C E
$^{18}_8 O_{10}$			0						C
$^{18}_8 O_{10}$	1980	3.3ps	[2]	$\pm 0.4$ to $0.7$					J
$^{17}_9 F_8$		66s	[5/2]	$\pm 4.722$	2				E
$^{18}_9 F_9$	1125	153ns	[5]	+2.85					J
$^{19}_9 F_{10}$			1/2	+2.6288	12				B C E F G H J
$^{19}_9 F_{10}$	197	89ns	[5/2]	+3.60		$\pm 0.11^s$			J
$^{20}_9 F_{11}$		11s	[2]	+2.094	1	$\pm 0.06^r$			E J
$^{19}_{10} Ne_9$		18s	1/2	-1.887	1				F
$^{19}_{10} Ne_9$	238	17.7ns	[5/2]	-0.74					J
$^{20}_{10} Ne_{10}$			0 <sup>d</sup>						F G
$^{20}_{10} Ne_{10}$	1630	0.7ps	[2]			-0.25			K
$^{21}_{10} Ne_{11}$			3/2	-0.66176	36	+0.09			F G
$^{22}_{10} Ne_{12}$			0 <sup>d</sup>						G
$^{22}_{10} Ne_{12}$	1275	3ps	[2]			-0.21			K
$^{23}_{10} Ne_{13}$		38s	[5/2]	-1.08					F

## Summary of Nuclear Moment Values and Index — Continued

Nucleus	Level (keV)	$T_{1/2}$	$I$ ( $h/2\pi$ )	$\mu$ (nm)	Diam. Corr.	$Q$ (b)	$\Omega$ (nmb)	$Q_4$ ( $b^2$ )	Index
$^{20}_{11}\text{Na}_9$	583	408ms	2	$\pm 0.369$	15	$+0.10^*$			H J
$^{21}_{11}\text{Na}_{10}$		23s	3/2	$+2.3861$					F H
$^{22}_{11}\text{Na}_{11}$		2.6y	3	$+1.746$					F
$^{22}_{11}\text{Na}_{11}$		243ns	[1]	$+0.55$					J
$^{23}_{11}\text{Na}_{12}$			3/2	$+2.21740^t$ ( $+2.21755$ )					E F G H
$^{24}_{11}\text{Na}_{13}$	1368	15h	4	$+1.690$	1				F
$^{24}_{12}\text{Mg}_{12}$			0 <sup>*</sup>						G
$^{24}_{12}\text{Mg}_{12}$		1ps	[2]						K
$^{25}_{12}\text{Mg}_{13}$			5/2	$-0.8554$					B E F G
$^{26}_{12}\text{Mg}_{14}$			0 <sup>*</sup>						G
$^{27}_{13}\text{Al}_{14}$	1779		5/2	$+3.6413$	29	$+0.15^*{}^b$ [ $\pm 0.3$ ]		E F G H	K
$^{28}_{14}\text{Si}_{14}$			0 <sup>*</sup>						C E
$^{28}_{14}\text{Si}_{14}$		0.5ps	[2]						K
$^{29}_{14}\text{Si}_{15}$			1/2	$-0.55526$					C E
$^{30}_{14}\text{Si}_{16}$			0 <sup>*</sup>						C
$^{29}_{15}\text{P}_{14}$	2237	4.2s	[1/2]	$\pm 1.235$	1			E J	
$^{30}_{15}\text{P}_{15}$		2.6m	1						F
$^{31}_{15}\text{P}_{16}$			1/2	$+1.1317$					B C E F G
$^{32}_{15}\text{P}_{17}$		14d	1	$-0.2523$					B
$^{32}_{16}\text{S}_{16}$			0						G
$^{32}_{16}\text{S}_{16}$	0.3My	0.25ps	[2]		7	$-0.2$ $-0.055^s$		C D E	K
$^{33}_{16}\text{S}_{17}$			3/2	$+0.6435$					C
$^{34}_{16}\text{S}_{18}$			0 <sup>*</sup>						C D
$^{35}_{16}\text{S}_{19}$		87d	3/2	$+1.00$ or $-1.07$					
$^{36}_{16}\text{S}_{20}$			0 <sup>*</sup>						C
$^{35}_{17}\text{Cl}_{18}$	1980		3/2	$+0.82181$	94	$-0.10^s$ $-0.016^s$		C D E F	
$^{36}_{17}\text{Cl}_{19}$		0.3My	2	$+1.2853$					C E
$^{37}_{17}\text{Cl}_{20}$			3/2	$+0.68407$					C D E F
$^{35}_{18}\text{Ar}_{17}$	1610	1.8s	[3/2]	$+0.632^s$	+0.11			F G	K
$^{36}_{18}\text{Ar}_{18}$			0 <sup>*</sup>						
$^{36}_{18}\text{Ar}_{18}$		?	[2]						
$^{37}_{18}\text{Ar}_{19}$		34d	3/2	$+0.95$					G
$^{37}_{18}\text{Ar}_{19}$		4.5ns	[7/2]	$-1.33$					J
$^{38}_{18}\text{Ar}_{20}$	1460		0 <sup>*</sup>		$\sim 0$			G G G	
$^{39}_{18}\text{Ar}_{21}$		265y	7/2	$-1.3$					
$^{40}_{18}\text{Ar}_{22}$			0 <sup>*</sup>						
$^{40}_{18}\text{Ar}_{22}$		0.8ps	[2]						K
$^{36}_{19}\text{K}_{17}$		245ms	2	$\pm 0.548$					H J
$^{37}_{19}\text{K}_{18}$	1290	1.2s	3/2	$+0.2032$	3			H	
$^{37}_{19}\text{K}_{18}$		10.5ns	[7/2]	$+5.2$					
$^{38}_{19}\text{K}_{19}$		7.7m	3	$+1.374$					J
$^{39}_{19}\text{K}_{20}$			3/2	$+0.39143^t$ ( $+0.39147$ )					F E F G H
$^{40}_{19}\text{K}_{21}$		1.3Gy	4	$-1.2981$					D F H
$^{41}_{19}\text{K}_{22}$	1290		3/2	$(+0.21487)^t$	28	$-0.061^r$ $+0.060^r$		E F H	
$^{41}_{19}\text{K}_{22}$		7.3ns	[7/2]	$+4.41$					J

## Summary of Nuclear Moment Values and Index — Continued

Nucleus	Level (keV)	$T_{1/2}$	$I$ ( $h/2\pi$ )	$\mu$ (nm)	Diam. Corr.	$Q$ (b)	$\Omega$ (nmb)	$Q_4$ ( $b^2$ )	Index
$^{42}_{19}K_{23}$		12h	2	-1.1424	15				F
$^{43}_{19}K_{24}$		22h	3/2	$\pm 0.163$					F
$^{45}_{19}K_{26}$		20m	3/2	$\pm 0.1734$	2				F
$^{40}_{20}Ca_{20}$		0*							G
$^{40}_{20}Ca_{20}$	3740	4lps	[3]	+0.4 <sup>p</sup>					J
$^{40}_{20}Ca_{20}$	4490	272ps	[5]	+1.6 <sup>p</sup>					J
$^{41}_{20}Ca_{21}$		110ky	7/2	-1.5946	23				E
$^{42}_{20}Ca_{22}$	3190	5.5ns	[6]	-2.8					J
$^{43}_{20}Ca_{23}$			7/2	-1.3172	19	$<\pm 0.2$			E F G H
$^{41}_{21}Sc_{20}$		0.59s	[7/2]	$\pm 5.43^p$	1				E J
$^{43}_{21}Sc_{22}$		3.9h	7/2	+4.62	1	-0.26 <sup>r</sup>			F J
$^{43}_{21}Sc_{22}$	3123	450ns	[19/2]	+3.14					
$^{44}_{21}Sc_{23}$		3.9h	2	+2.56		+0.11 <sup>r</sup>			F
$^{44}_{21}Sc_{23}$	69	153ns	[1]	+0.34		$\pm 0.18^*$			J
$^{44}_{21}Sc_{23}$	270	2.4d	6	+3.88	1	-0.20 <sup>r</sup>			F
$^{45}_{21}Sc_{24}$			7/2	+4.7559	72	-0.22 <sup>s</sup>			E F G
$^{46}_{21}Sc_{25}$		84d	4	+3.03		+0.12 <sup>r</sup>			F
$^{47}_{21}Sc_{26}$		3.4d	7/2	+5.34	1	-0.22 <sup>r</sup>			F
$^{47}_{21}Sc_{26}$	767	274ns	[3/2]	$\pm 0.35$					J
$^{48}_{21}Sc_{27}$		1.8d	6						F
$^{45}_{22}Ti_{23}$		3.1h	7/2	$\pm 0.095$		$\sim \pm 0.02^r$			F
						$\mu/Q$ positive			
$^{46}_{22}Ti_{24}$	889	7ps	[2]			-0.2			K
$^{47}_{22}Ti_{25}$			5/2	-0.78846	127	+0.29 <sup>s</sup>			
$^{48}_{22}Ti_{26}$	983	3.6ps	[2]			-0.20			K
$^{49}_{22}Ti_{27}$			7/2	-1.10414	177	+0.24 <sup>r</sup>			
$^{50}_{22}Ti_{28}$	1550	1ps	[2]			$\sim 0$			K
$^{47}_{23}V_{24}$		31m	3/2						F
$^{48}_{23}V_{25}$		16d	4	$\pm 1.6$					F J
$^{48}_{23}V_{25}$	306	7.09ns	[2]	+0.38					J
$^{49}_{23}V_{26}$		330d	7/2	$\pm 4.5^p$					
$^{50}_{23}V_{27}$		>40Jy	6	+3.3470	57	$\pm 0.06$			B E
$^{51}_{23}V_{28}$			7/2	+5.1485	88	-0.05 <sup>b</sup>			E F G
$^{51}_{23}V_{28}$	320	173ps	[5/2]	+4.0					J
$^{49}_{24}Cr_{25}$		42m	5/2	$\pm 0.476$	1				F
$^{50}_{24}Cr_{26}$	783	8.4ps	[2]			-0.3			K
$^{51}_{24}Cr_{27}$		28d	7/2	$\pm 0.934$	2				F
$^{51}_{24}Cr_{27}$	749	7.5ns	[3/2]	$\pm 1.1$					J
$^{52}_{24}Cr_{28}$	1434	0.90ps	[2]			[ $-0.08$ ]			K
$^{53}_{24}Cr_{29}$			3/2	-0.4735 <sup>E</sup>	9	+0.03			B E F H K
$^{54}_{24}Cr_{30}$	834	8.9ps	[2]	(-0.4744)					K
						-0.1			
$^{51}_{25}Mn_{26}$		45m	5/2	$\pm 3.56^E$					F
$^{52}_{25}Mn_{27}$		5.7d	6	+3.059 <sup>E</sup>	6	+0.6 <sup>r</sup>			E F J
$^{52}_{25}Mn_{27}$	383	21m	2	$\pm 0.0076$					F
$^{53}_{25}Mn_{28}$		2My	7/2	$\pm 5.02^E$	1				B
$^{54}_{25}Mn_{29}$		312d	3	+3.278 <sup>E</sup>	6	+0.4 <sup>r</sup>			E J
$^{55}_{25}Mn_{30}$			5/2	+3.449 <sup>E</sup>	7	+0.4 <sup>s</sup>			B C E F G H
$^{56}_{25}Mn_{31}$		2.6h	3	(+3.4680)	66				F J
				+3.223 <sup>E</sup>	6				

## Summary of Nuclear Moment Values and Index — Continued

Nucleus	Level (keV)	$T_{1/2}$	$I$ ( $\hbar/2\pi$ )	$\mu$ (nm)	Diam. Corr.	$Q$ (b)	$\Omega$ (nmb)	$Q_4$ ( $b^2$ )	Index
$^{54}_{26}\text{Fe}_{28}$	1408	1.0ps	[2]	+2.9					J
$^{54}_{26}\text{Fe}_{28}$	2950	1.22ns	[6]	$\pm 8.2$					J
$^{56}_{26}\text{Fe}_{30}$	847	6.9ps	[2]	+1.2					J K
$^{57}_{26}\text{Fe}_{31}$			1/2	+0.09042 <sup>E</sup> (+0.09060)	18	-0.26			K
$^{57}_{26}\text{Fe}_{31}$	14.4	~10ns	[3/2]	-0.1550	3	+0.19*			I
$^{57}_{26}\text{Fe}_{31}$	136	8.8ns	[5/2]	+0.92					I J
$^{57}_{26}\text{Fe}_{31}$	367	7ps	[3/2]	<0.5					I J
$^{57}_{26}\text{Fe}_{31}$	707	3ps	[5/2]	< $\pm 1$					J
$^{58}_{26}\text{Fe}_{32}$	811	6.4ps	[2]	+1.1					J
$^{59}_{26}\text{Fe}_{33}$		45d	3/2	$\pm 1.1$				F	J
$^{55}_{27}\text{Co}_{28}$		18h	[7/2]	$\pm 4.5$					J
$^{56}_{27}\text{Co}_{29}$		77d	4	$\pm 3.83$	1			B	
$^{57}_{27}\text{Co}_{30}$		270d	7/2	+4.72	1	+0.5 <sup>r</sup>		B	E J
$^{57}_{27}\text{Co}_{30}$	1378	19.4ps	[3/2]	+3				B	J
$^{58}_{27}\text{Co}_{31}$		71.3d	2	+4.04	1	+0.2 <sup>r</sup>		B	E J
$^{58}_{27}\text{Co}_{31}$	54	10.2 $\mu$ s	[4]	+4.18				B	J
$^{59}_{27}\text{Co}_{32}$			7/2	+4.616	10	+0.38 <sup>S</sup>		B E F G	
$^{59}_{27}\text{Co}_{32}$	1292	564ps	[3/2]	+1.8				B	J
$^{60}_{27}\text{Co}_{33}$		5.26y	5	+3.79	1	+0.4 <sup>r</sup>		B E	J
$^{60}_{27}\text{Co}_{33}$	58	10.5m	2	+4.4		+0.3 <sup>r</sup>		F	
$^{58}_{28}\text{Ni}_{30}$	1450	0.67ps	[2]			-0.14			K
$^{60}_{28}\text{Ni}_{32}$	1330	0.80ps	[2]			[−0.10]			K
$^{61}_{28}\text{Ni}_{33}$			3/2	-0.7498	17	+0.16*		B E F G	
$^{61}_{28}\text{Ni}_{33}$	68	5.2ns	[5/2]	+0.42					I
$^{62}_{28}\text{Ni}_{34}$	1170	1.57ps	[2]			+0.2			K
$^{63}_{28}\text{Ni}_{35}$	87.2	1.72 $\mu$ s	[5/2]	+0.752 <sup>S</sup>					J
$^{64}_{28}\text{Ni}_{36}$	1350	0.78ps	[2]			+0.3			K
$^{60}_{29}\text{Cu}_{31}$		24m	2	+1.219	3			F	
$^{61}_{29}\text{Cu}_{32}$		3.3h	3/2	+2.13				F	
$^{62}_{29}\text{Cu}_{33}$		9.9m	1	-0.380	1			F	
$^{62}_{29}\text{Cu}_{33}$	41	4.80ns	[2]	$\pm 1.3$					J
$^{62}_{29}\text{Cu}_{33}$	390	11.5ns	[3]	$\pm 1.9$					J
$^{63}_{29}\text{Cu}_{34}$			3/2	+2.2228 <sup>r</sup> (+2.2262)	53	-0.2111* <sup>r</sup>		B D E F G H	
$^{64}_{29}\text{Cu}_{35}$		13h	1	-0.216				F	
$^{64}_{29}\text{Cu}_{35}$	1590	20.4ns	[6]	+1.04					J
$^{65}_{29}\text{Cu}_{36}$			3/2	+2.3812 <sup>r</sup> (+2.3849)	57	-0.1951* <sup>S</sup>		B D E F G H	
$^{66}_{29}\text{Cu}_{37}$		5.2m	1	-0.281	1			F	
$^{66}_{29}\text{Cu}_{37}$	1154	596ns	[6]	+1.04					J
$^{63}_{30}\text{Zn}_{33}$		38m	3/2	-0.2816	7	+0.29 <sup>r</sup>			H
$^{64}_{30}\text{Zn}_{34}$		0*						G	
$^{64}_{30}\text{Zn}_{34}$	992	2.7ps	[2]			[−0.14]			K
$^{65}_{30}\text{Zn}_{35}$		245d	5/2	+0.7692	19	-0.024 <sup>r</sup>			H
$^{66}_{30}\text{Zn}_{35}$		0*						G	
$^{67}_{30}\text{Zn}_{36}$			5/2	+0.87524 <sup>d</sup> (+0.8756)	218	+0.16 <sup>S</sup>		E F G H	
$^{67}_{30}\text{Zn}_{37}$	185	1.01ns	[3/2]	+0.4					J
$^{67}_{30}\text{Zn}_{37}$	605	340ns	[9/2]	-1.09					J
$^{68}_{30}\text{Zn}_{38}$		0*						G	
$^{70}_{30}\text{Zn}_{40}$	884	3ps	[2]			[−0.2]			K

## Summary of Nuclear Moment Values and Index — Continued

Nucleus	Level (keV)	$T_{1/2}$	$I$ ( $h/2\pi$ )	$\mu$ (nm)	Diam. Corr.	$Q$ (b)	$\Omega$ (nmb)	$Q_4$ ( $b^2$ )	Index
$^{66}_{31}\text{Ga}_{35}$		9.5h	0 <sup>+</sup>						F
$^{67}_{31}\text{Ga}_{36}$		78h	3/2	+1.849 <sup>f</sup>	5	+0.22 <sup>r</sup>			F
$^{68}_{31}\text{Ga}_{37}$		68m	1	$\pm 0.0117$		$\pm 0.031^r$			F
$^{69}_{31}\text{Ga}_{38}$			3/2	+2.0145 <sup>t</sup> (+2.0161) <sup>r</sup>	53	+0.19 <sup>s</sup>	+0.14		C D E F G
$^{70}_{31}\text{Ga}_{39}$		21m	1						F
$^{71}_{31}\text{Ga}_{40}$			3/2	+2.5597 <sup>t</sup> (+2.5617)	67	+0.12 <sup>r</sup>	+0.18		C D E F G
$^{72}_{31}\text{Ga}_{41}$		14h	3	-0.1321 <sup>t</sup>	3	+0.59 <sup>r</sup>			F
$^{67}_{32}\text{Ge}_{35}$	734	70ns	[9/2]	-0.94		$Q/Q_{39g}^{69}=1.22$			J
$^{69}_{32}\text{Ge}_{37}$		38h	5/2	$\pm 0.73$		$\pm 0.03^r$			F
$^{69}_{32}\text{Ge}_{37}$	398	3μs	[9/2]	-1.001	3	$\mu/Q$ positive			J
$^{70}_{32}\text{Ge}_{38}$			0 <sup>+</sup>						C
$^{70}_{32}\text{Ge}_{38}$	1040	1.3ps	[2]	+1.8		~0			J K
$^{71}_{32}\text{Ge}_{39}$		11d	1/2	+0.546	1				F
$^{71}_{32}\text{Ge}_{39}$	175	79ns	[5/2]	+1.02		$Q/Q_{39g}^{69}=0.22$			J
$^{71}_{32}\text{Ge}_{39}$	198	20.2ms	[9/2]	-1.040	3	$\pm 0.3$			J
$^{72}_{32}\text{Ge}_{40}$			0 <sup>+</sup>						C
$^{72}_{32}\text{Ge}_{40}$	835	3.14ps	[2]	+1.2					J
$^{73}_{32}\text{Ge}_{41}$			9/2	-0.87918	240	-0.18			C E F
$^{74}_{32}\text{Ge}_{42}$			0 <sup>+</sup>						C
$^{74}_{32}\text{Ge}_{42}$	596	12ps	[2]	+0.9		~0			F
$^{75}_{32}\text{Ge}_{43}$		82m	1/2	+0.51					C
$^{76}_{32}\text{Ge}_{44}$			0 <sup>+</sup>						J K
$^{76}_{32}\text{Ge}_{44}$	563	17.6ps	[2]	+0.7		-0.2;~0			J K
$^{70}_{33}\text{As}_{37}$		55m	4						F
$^{72}_{33}\text{As}_{39}$		26h	2	$\pm 2.2$					F
$^{72}_{33}\text{As}_{39}$	215	80ns	[3]	+1.58					J
$^{73}_{33}\text{As}_{40}$	66.9	5.0ns	[5/2]	+1.6					J
$^{73}_{33}\text{As}_{40}$	427	5.8μs	[9/2]	+5.21	1				E
$^{74}_{33}\text{As}_{41}$	274	26.8ns	[3]	+2.43	1				J
$^{75}_{33}\text{As}_{42}$			3/2	+1.439	4	+0.29			B C D E F G
$^{75}_{33}\text{As}_{42}$	265	11.9ps	[3/2]	+1.0					J
$^{75}_{33}\text{As}_{42}$	280	0.28ns	[5/2]	+0.9					J
$^{76}_{33}\text{As}_{43}$		26h	2	-0.905	2	$\pm 7.8$			B F
$^{76}_{33}\text{As}_{43}$	45	2.60μs	[1]	+0.559	1				J
$^{77}_{33}\text{As}_{44}$	473	116μs	[9/2]	$\pm 5.52$	1				J
$^{74}_{34}\text{Se}_{40}$			0 <sup>+</sup>						C
$^{75}_{34}\text{Se}_{41}$		120d	5/2			+1.0 <sup>r</sup>			C
$^{76}_{34}\text{Se}_{42}$			0 <sup>+</sup>						C G
$^{76}_{34}\text{Se}_{42}$	559	11.1ps	[2]	+0.8					J
$^{77}_{34}\text{Se}_{43}$			1/2	+0.534	1				C E G
$^{77}_{34}\text{Se}_{43}$	249	9.4ns	[5/2]	+1.2					J
$^{77}_{34}\text{Se}_{43}$	440	24ps	[5/2]	+1.0					J
$^{78}_{34}\text{Se}_{44}$			0						C G
$^{78}_{34}\text{Se}_{44}$	614	8.6ps	[2]	+0.8					J
$^{79}_{34}\text{Se}_{45}$		60ky	7/2	-1.02		+0.8 <sup>s</sup>			C
$^{80}_{34}\text{Se}_{46}$			0						C G
$^{80}_{34}\text{Se}_{46}$	666	8.05ps	[2]	+0.8					J
$^{82}_{34}\text{Se}_{48}$			0 <sup>+</sup>						C G
$^{82}_{34}\text{Se}_{48}$	655	11.3ps	[2]	+0.9					J

## Summary of Nuclear Moment Values and Index -- Continued

Nucleus	Level (keV)	$T_{1/2}$	$I$ ( $h/2\pi$ )	$\mu$ (nm)	Diam. Corr.	$Q$ (b)	$\Omega$ (nmb)	$Q_4$ ( $b^2$ )	Index
$^{76}_{35}\text{Br}_{41}$		17h	1	$\pm 0.548$	2	$\pm 0.30^{*r}$ $\mu/Q$ negative			F
$^{77}_{35}\text{Br}_{42}$		58h	3/2						F
$^{78}_{35}\text{Br}_{43}$	181	100 $\mu$ s	[4]	+4.11	1				E
$^{79}_{35}\text{Br}_{44}$			3/2	+2.1055	65	$+0.37^{*s}$	+0.09*		C D E F G
$^{80}_{35}\text{Br}_{45}$		18m	1	$\pm 0.514$	2	$\pm 0.22^{*r}$			F
						$\mu/Q$ positive			
$^{80}_{35}\text{Br}_{45}$	85	4.5h	5	+1.317	4	$+0.84^{*r}$			F
$^{81}_{35}\text{Br}_{46}$			3/2	+2.2696	70	$+0.31^{*r}$	+0.10*		C D E F G
$^{81}_{35}\text{Br}_{46}$	540	35 $\mu$ s	[9/2]	$\pm 5.77$	2				E
$^{82}_{35}\text{Br}_{47}$		36h	5	+1.626	5	$\pm 0.84^{*r}$			J
									F
$^{79}_{36}\text{Kr}_{43}$	148	77.7ns	[5/2]	+1.12					J
$^{82}_{36}\text{Kr}_{46}$			0*						G
$^{83}_{36}\text{Kr}_{47}$			9/2	-0.9703	31	$+0.26^s$	-0.18		E F G
$^{83}_{36}\text{Kr}_{47}$	9.3	143ns	[7/2]	-1.8		$+0.44^r$			I J
$^{84}_{36}\text{Kr}_{48}$			0*						G
$^{85}_{36}\text{Kr}_{49}$		11y	9/2	$\pm 1.005$	3	$+0.43^r$			F G
$^{86}_{36}\text{Kr}_{50}$			0*						G
$^{81}_{37}\text{Rb}_{44}$		4.7h	3/2	+2.05					F
$^{81}_{37}\text{Rb}_{44}$	85	32m	9/2						F
$^{82}_{37}\text{Rb}_{45}$	30	6.3h	5	+1.643	6				F
$^{83}_{37}\text{Rb}_{46}$		83d	5/2	+1.42					F
$^{84}_{37}\text{Rb}_{47}$		33d	2	-1.32					F
$^{85}_{37}\text{Rb}_{48}$			5/2	+1.3524 <sup>df</sup> (+1.3527)	45	$+0.26^s$			E F G H
$^{86}_{37}\text{Rb}_{49}$		19d	2	-1.691	6				F
$^{87}_{37}\text{Rb}_{50}$		47Gy	3/2	+2.7500 <sup>df</sup> (+2.7506)	92	$+0.13^{*r}$			E F G H
$^{88}_{37}\text{Rb}_{51}$		18m	2	$\pm 0.51$					F
$^{86}_{38}\text{Sr}_{48}$	?	460ns	0*						G
$^{86}_{38}\text{Sr}_{48}$			[8]	-1.9					J
$^{87}_{38}\text{Sr}_{49}$			9/2	-1.093	4	$+0.3$			B E F G H
$^{88}_{38}\text{Sr}_{50}$			0*						G
$^{86}_{39}\text{Y}_{47}$	243	28.5ns	[2]	-1.06					J
$^{89}_{39}\text{Y}_{50}$			1/2	-0.13733	49				E F G H
$^{90}_{39}\text{Y}_{51}$		64h	2	-1.63	1	-0.15			F
$^{91}_{39}\text{Y}_{52}$		58d	1/2	$\pm 0.164$	1				F
$^{90}_{40}\text{Zr}_{50}$	3590	130ns	[8]	$\pm 10.8$					J
$^{91}_{40}\text{Zr}_{51}$			5/2	-1.3028	48				E G
$^{91}_{40}\text{Zr}_{51}$	>2265	29.0ns	[15/2]	$\pm 5.3$					J
$^{91}_{41}\text{Nb}_{50}$	2378	10.0ns	[17/2]	$\pm 10.6$					J
$^{93}_{41}\text{Nb}_{52}$			9/2	+6.167	24	-0.22			B E G
$^{95}_{41}\text{Nb}_{54}$		35d	[9/2]	$\pm 6.3$					J
$^{92}_{42}\text{Mo}_{50}$			0*						G
$^{92}_{42}\text{Mo}_{50}$	2761	190ns	[8]	$\pm 11.2$					J
$^{94}_{42}\text{Mo}_{52}$			0*						G
$^{94}_{42}\text{Mo}_{52}$	2953	97.7ns	[8]	+10.5					J
$^{95}_{42}\text{Mo}_{53}$			5/2	-0.9135	36	$\pm 0.12$			B E G
$^{95}_{42}\text{Mo}_{53}$	204	760ps	[3/2]	-0.4					J
$^{96}_{42}\text{Mo}_{54}$			0*						G

## Summary of Nuclear Moment Values and Index — Continued

Nucleus	Level (keV)	$T_{1/2}$	$I$ ( $\hbar/2\pi$ )	$\mu$ (nm)	Diam. Corr.	$Q$ (b)	$\Omega$ (nmb)	$Q_4$ ( $b^2$ )	Index		
$^{97}_{42}\text{Mo}_{55}$			5/2	-0.9327	37	$\pm 1.1$			B	E	G
$^{98}_{42}\text{Mo}_{56}$			0 <sup>a</sup>								G
$^{98}_{42}\text{Mo}_{56}$	787	3.5ps	[2]	+0.7							J
$^{100}_{42}\text{Mo}_{58}$			0 <sup>a</sup>								G
$^{100}_{42}\text{Mo}_{58}$	536	10ps	[2]	+0.7							J
$^{96}_{43}\text{Tc}_{53}$		4.3d	6	$\pm 4.6$					B	E	J
$^{99}_{43}\text{Tc}_{56}$		210ky	9/2	+5.681	23	+0.3			B	E	G
$^{99}_{43}\text{Tc}_{56}$	141	192ps	[7/2]	+5							J
$^{99}_{43}\text{Tc}_{56}$	181	3.59ns	[5/2]	+3.3							J
$^{98}_{44}\text{Ru}_{54}$	654	5.9ps	[2]	+0.8							J
$^{99}_{44}\text{Ru}_{55}$			5/2	-0.62					B	G	I J
$^{99}_{44}\text{Ru}_{55}$	90	20.7ns	3/2	-0.28							I J
$^{100}_{44}\text{Ru}_{56}$	540	11.9ps	[2]	+1.0							J
$^{101}_{44}\text{Ru}_{57}$			5/2	-0.68					B	G	
$^{101}_{44}\text{Ru}_{57}$	127	550ps	[3/2]	-0.31							J
$^{102}_{44}\text{Ru}_{58}$	475	17.6ps	[2]	+0.74							J
$^{104}_{44}\text{Ru}_{60}$	358	58ps	[2]	+0.8							J
$^{100}_{45}\text{Rh}_{55}$	74.8	215ns	[2]	+4.32	2						J
$^{103}_{45}\text{Rh}_{58}$			1/2	-0.0883	4				E	G	
$^{103}_{45}\text{Rh}_{58}$	93	1.13ns	[9/2]	$\pm 6.2$							J
$^{103}_{45}\text{Rh}_{58}$	298	6.3ps	[3/2]	+1 <sup>b</sup>							J
$^{103}_{45}\text{Rh}_{58}$	360	59ps	[5/2]	+1.2 <sup>b</sup>							J
$^{104}_{46}\text{Pd}_{58}$	556	9.7ps	[2]	+0.7							J K
$^{105}_{46}\text{Pd}_{59}$			5/2	-0.642	3	+0.8			E	F	G
$^{106}_{46}\text{Pd}_{60}$	512	12.7ps	[2]	+0.73							J K
$^{106}_{46}\text{Pd}_{60}$	1128	2.5ps	[2]	+0.7							J
$^{108}_{46}\text{Pd}_{62}$	434	23.8ps	[2]	+0.77							J K
$^{110}_{46}\text{Pd}_{64}$	374	45.8ps	[2]	+0.70							J K
$^{101}_{47}\text{Ag}_{54}$		9m	9/2								F
$^{102}_{47}\text{Ag}_{55}$		13m	5								F
$^{102}_{47}\text{Ag}_{55}$	?	7m	2	+4.2							F
$^{103}_{47}\text{Ag}_{56}$		66m	7/2	+4.45 <sup>a</sup>							F
$^{104}_{47}\text{Ag}_{57}$		1.2h	5	+4.0							F
$^{104}_{47}\text{Ag}_{57}$	~20	27m	2	+3.7							F
$^{105}_{47}\text{Ag}_{58}$		40d	1/2	$\pm 0.101$							F
$^{106}_{47}\text{Ag}_{59}$		24m	1	+2.9							F
$^{106}_{47}\text{Ag}_{59}$	~300	8.3d	6								F
$^{107}_{47}\text{Ag}_{60}$			1/2	-0.1135	5				E	F	G
$^{107}_{47}\text{Ag}_{60}$	325	5.9ps	[3/2]	+0.7							J
$^{107}_{47}\text{Ag}_{60}$	423	34ps	[5/2]	+0.9							J
$^{108}_{47}\text{Ag}_{61}$		2.4m	1	+2.80	1						F
$^{109}_{47}\text{Ag}_{62}$			1/2	-0.1305	6				E	F	G
$^{109}_{47}\text{Ag}_{62}$	88	40s	7/2	$\pm 4.3$							F
$^{109}_{47}\text{Ag}_{62}$	309	5.2ps	[3/2]	+0.9							J
$^{109}_{47}\text{Ag}_{62}$	414	33ps	[5/2]	+0.9							J
$^{110}_{47}\text{Ag}_{63}$		24.4s	1	+2.72	1				E	F	
$^{110}_{47}\text{Ag}_{63}$	116	253d	6	+3.604	17				B	F	J
$^{111}_{47}\text{Ag}_{64}$		7.5d	1/2	-0.145	1						F
$^{112}_{47}\text{Ag}_{65}$		3.2h	2	$\pm 0.054$							F
$^{113}_{47}\text{Ag}_{66}$		5.3h	1/2	$\pm 0.159$	1						F

## Summary of Nuclear Moment Values and Index - Continued

Nucleus	Level (keV)	$T_{1/2}$	$I$ ( $\hbar/2\pi$ )	$\mu$ (nm)	Diam. Corr.	$Q$ (b)	$\Omega$ (nmb)	$Q_4$ ( $b^2$ )	Index
$^{105}_{48}\text{Cd}_{57}$		55m	5/2	-0.738	4	+0.43 <sup>r</sup>			H
$^{106}_{48}\text{Cd}_{58}$	633	6ps	[2]			-0.8			K
$^{107}_{48}\text{Cd}_{59}$		6.7h	5/2	-0.61443 <sup>d</sup>	294	+0.68 <sup>r</sup>			H
$^{108}_{48}\text{Cd}_{60}$	633	5ps	[2]			-0.8			K
$^{109}_{48}\text{Cd}_{61}$		470d	5/2	-0.82701 <sup>d</sup>	395	+0.69 <sup>s</sup>			H
$^{109}_{48}\text{Cd}_{61}$	469	8.9 $\mu$ s	[11/2]	-1.10	1				J
$^{110}_{48}\text{Cd}_{62}$		0 <sup>*</sup>							G
$^{110}_{48}\text{Cd}_{62}$	656	5.0ps	[2]	+0.7		-0.5;-0.3 <sup>b</sup>			J K
$^{111}_{48}\text{Cd}_{63}$			1/2	-0.59428 <sup>d</sup> (-0.59500)	284				E F G H
$^{111}_{48}\text{Cd}_{63}$	247	84ns	[5/2]	-0.793	4	+1			J
$^{111}_{48}\text{Cd}_{63}$	397	49m	11/2	-1.1040	53	-0.85 <sup>r</sup>			H
$^{112}_{48}\text{Cd}_{64}$		0 <sup>*</sup>							G
$^{112}_{48}\text{Cd}_{64}$	617	6.2ps	[2]	+0.7		-0.2			J K
$^{113}_{48}\text{Cd}_{65}$		>3Jy	1/2	-0.62167 <sup>d</sup> (-0.62245)	297				E F G H
$^{113}_{48}\text{Cd}_{65}$	265	14y	11/2	-1.0871 <sup>d</sup>	52	-0.71 <sup>r</sup>			H
$^{114}_{48}\text{Cd}_{66}$		0 <sup>*</sup>							G
$^{114}_{48}\text{Cd}_{66}$	558	9.0ps	[2]	+0.8		-0.32			J K
$^{115}_{48}\text{Cd}_{67}$		2.3d	1/2	-0.6478 <sup>d</sup>	31				H
$^{115}_{48}\text{Cd}_{67}$	180	43d	11/2	-1.0400 <sup>d</sup>	50	-0.55 <sup>r</sup>			H
$^{116}_{48}\text{Cd}_{68}$		0 <sup>*</sup>							G
$^{116}_{48}\text{Cd}_{68}$	513	13.7ps	[2]	+0.8		-0.9 <sup>b</sup>			J K
$^{109}_{49}\text{In}_{60}$		4.3h	9/2	+5.53	3	+0.85 <sup>r</sup>			F
$^{110}_{49}\text{In}_{61}$		66m	2	+4.36	2	+0.36 <sup>r</sup>			F
$^{110}_{49}\text{In}_{61}$	?	4.9h	7	+10.4 or -10.7		-0.21 <sup>r</sup> or +0.22 <sup>r</sup>			F
$^{111}_{49}\text{In}_{62}$		2.8d	9/2	+5.53	3	+0.84 <sup>r</sup>			F
$^{112}_{49}\text{In}_{63}$		14m	1	+2.81	1	+0.089 <sup>r</sup>			F
$^{112}_{49}\text{In}_{63}$	155	21m	4						F
$^{113}_{49}\text{In}_{64}$			9/2	+5.5229	271	+0.82 <sup>r</sup>	+0.57		E F G H
$^{113}_{49}\text{In}_{64}$	393	1.7h	1/2	-0.210	1				F
$^{114}_{49}\text{In}_{65}$		72s	[1]	$\leq \pm 1.7$					J
$^{114}_{49}\text{In}_{65}$	190	50d	5	+4.7					F
$^{115}_{49}\text{In}_{66}$		600Ty	9/2	+5.5348	272	+0.83 <sup>s</sup>	+0.56		C E F G H
$^{115}_{49}\text{In}_{66}$	335	4.5h	1/2	-0.244	1				F
$^{116}_{49}\text{In}_{67}$		14s	[1]	$\pm 2.786$	14	$\pm 0.1$			E J
$^{116}_{49}\text{In}_{67}$	70	54m	5	+4.3					F
$^{117}_{49}\text{In}_{68}$		45m	9/2						F
$^{117}_{49}\text{In}_{68}$	310	1.9h	1/2	-0.2515	12				F
$^{117}_{49}\text{In}_{68}$	660	60ns	[3/2]	+1.0		$\pm 0.64$			J
$^{112}_{50}\text{Sn}_{62}$	1257	0.3ps	[2]			$\sim 0$			K
$^{113}_{50}\text{Sn}_{63}$		118d	1/2	$\pm 0.88$					F
$^{114}_{50}\text{Sn}_{64}$	~3100	700ns	[9,7?]	$g = -0.081$					J
$^{115}_{50}\text{Sn}_{65}$			1/2	-0.9178	46				E F G
$^{115}_{50}\text{Sn}_{65}$	619	3.3 $\mu$ s	[7/2]	$< \pm 1.0$					J
$^{115}_{50}\text{Sn}_{65}$	726	159 $\mu$ s	[11/2]	-1.368	7	$\pm 0.8$			E J
$^{116}_{50}\text{Sn}_{66}$		0 <sup>*</sup>							G
$^{116}_{50}\text{Sn}_{66}$	1290	0.4ps	[2]			$[-0.1]$			K
$^{116}_{50}\text{Sn}_{66}$	2369	350ns	[5]	-0.32					J
$^{117}_{50}\text{Sn}_{67}$		0 <sup>*</sup>	1/2	-0.9999	50				E F G
$^{118}_{50}\text{Sn}_{68}$	1230	0.5ps	[2]			-0.2			G
$^{118}_{50}\text{Sn}_{68}$	2320	21.7ns	[5]	-0.32					K

## Summary of Nuclear Moment Values and Index — Continued

Nucleus	Level (keV)	$T_{1/2}$	$I$ ( $h/2\pi$ )	$\mu$ (nm)	Diam. Corr.	$Q$ (b)	$\Omega$ (nmb)	$Q_4$ ( $b^2$ )	Index
$^{119}_{50}\text{Sn}_{69}$			1/2	-1.0461	53				B E F G I
$^{119}_{50}\text{Sn}_{69}$	24	18.5ns	[3/2]	+0.68		-0.07			G
$^{120}_{50}\text{Sn}_{70}$			0*						K
$^{120}_{50}\text{Sn}_{70}$	1170	0.5ps	[2]			~0			J
$^{120}_{50}\text{Sn}_{70}$	2300	5.5ns	[5]	-0.30		±0.02			F
$^{121}_{50}\text{Sn}_{71}$		27h	3/2	±0.699	4	±0.08			
						$\mu/Q$ negative			
$^{122}_{50}\text{Sn}_{72}$	1140	0.6ps	[2]			~0.3			K
$^{123}_{50}\text{Sn}_{73}$	~24	40m	3/2						F
$^{124}_{50}\text{Sn}_{74}$	1130	0.8ps	[2]			-0.1			K
$^{115}_{51}\text{Sb}_{64}$		31m	5/2	+3.46	2	-0.28 <sup>r</sup>			F
$^{116}_{51}\text{Sb}_{65}$		15m	3						F
$^{117}_{51}\text{Sb}_{66}$		2.8h	5/2	+2.67	1	-0.42 <sup>r</sup>			F
$^{117}_{51}\text{Sb}_{66}$	3130	340μs	[21/2?]	+1.22					J
$^{118}_{51}\text{Sb}_{67}$	~200	3.5m	1	±2.46	1				F
$^{119}_{51}\text{Sb}_{68}$		38h	5/2	+3.45	2	-0.29 <sup>r</sup>			F
$^{120}_{51}\text{Sb}_{69}$		16m	1	±2.3					F
$^{121}_{51}\text{Sb}_{70}$			5/2	+3.3592	174	-0.28 <sup>bs</sup>			B C D E F G I
$^{121}_{51}\text{Sb}_{70}$	37	3.5ns	[7/2]	+2.51	1	-0.4 <sup>r</sup>			I
$^{122}_{51}\text{Sb}_{71}$		2.73d	2	-1.90	1	+0.66 <sup>r</sup>			B F J
$^{122}_{51}\text{Sb}_{71}$	61	1.8μs	[3]	+2.98	2				J
$^{123}_{51}\text{Sb}_{72}$			7/2	+2.5466	132	-0.36 <sup>r</sup>			B C D E F G
$^{124}_{51}\text{Sb}_{73}$		60d	3	±1.3					F J
$^{125}_{51}\text{Sb}_{74}$		2.77y	7/2	±2.61	1				E J
$^{126}_{51}\text{Sb}_{75}$		12.5d	[8]	±1.3					J
$^{127}_{51}\text{Sb}_{76}$		3.9d	[7/2]	±2.6					J
$^{128}_{51}\text{Sb}_{77}$		8.6h	[8]	±1.3					J
$^{116}_{52}\text{Te}_{64}$		2.5h	0*						F
$^{117}_{52}\text{Te}_{65}$		61m	1/2						F
$^{119}_{52}\text{Te}_{67}$		16h	1/2	±0.25					F
$^{119}_{52}\text{Te}_{67}$	~300	4.5d	11/2						F
$^{120}_{52}\text{Te}_{68}$	560	9.3ps	[2]	+0.6					J
$^{122}_{52}\text{Te}_{70}$	564	7.6ps	[2]	+0.66					J
$^{123}_{52}\text{Te}_{71}$		>50Ty	1/2	-0.7359	39				E G
$^{123}_{52}\text{Te}_{71}$	159	190ps	[3/2]	±0.7					J
$^{123}_{52}\text{Te}_{71}$	248	117d	[11/2]	-1.00					J
$^{123}_{52}\text{Te}_{71}$	440	?	?	$g=+0.2$					J
$^{123}_{52}\text{Te}_{71}$	506	?	?	$g=+0.03$					J
$^{124}_{52}\text{Te}_{72}$	603	6.6ps	[2]	+0.5 <sup>b</sup>		-0.5;-0.3			J K
$^{125}_{52}\text{Te}_{73}$			1/2	-0.8872	47				E G
$^{125}_{52}\text{Te}_{73}$	35.5	1.6ns	3/2	+0.60		-0.2			I
$^{125}_{52}\text{Te}_{73}$	145	58d	[11/2]	±0.9					J
$^{125}_{52}\text{Te}_{73}$	321	695ps	[9/2]	-0.91					J
$^{125}_{52}\text{Te}_{73}$	443	21ps	[3/2]	+0.5					J
$^{125}_{52}\text{Te}_{73}$	463	13ps	[5/2]	+0.6					J
$^{125}_{52}\text{Te}_{73}$	525	?	[7/2?]	negative					J
$^{126}_{52}\text{Te}_{74}$			0*						G
$^{126}_{52}\text{Te}_{74}$	667	4.4ps	[2]	+0.6		-0.3;-0.1 <sup>b</sup>			J K
$^{127}_{52}\text{Te}_{75}$		9.4h	[3/2]	±0.61					J
$^{127}_{52}\text{Te}_{75}$	89	109d	[11/2]	-0.91					J
$^{128}_{52}\text{Te}_{76}$			0*						G
$^{128}_{52}\text{Te}_{76}$	743	3.2ps	[2]	+0.5		-0.1;+0.1 <sup>b</sup>			J K
$^{129}_{52}\text{Te}_{77}$		69m	[3/2]	±0.67					J
$^{129}_{52}\text{Te}_{77}$	106	34d	[11/2]	-1.15					J

## Summary of Nuclear Moment Values and Index — Continued

Nucleus	Level (keV)	$T_{1/2}$	$I$ ( $h/2\pi$ )	$\mu$ (nm)	Diam. Corr.	$Q$ (b)	$\Omega$ (nmb)	$Q_4$ ( $b^2$ )	Index
$^{130}_{52}\text{Te}_{78}$			0 <sup>d</sup>						G
$^{130}_{52}\text{Te}_{78}$	840	2.0ps	[2]	+0.6		-0.2; -0.1			J K
$^{123}_{53}\text{I}_{70}$		13h	5/2						F
$^{124}_{53}\text{I}_{71}$		4.0d	2						F
$^{125}_{53}\text{I}_{72}$		60d	5/2	+3		-0.89 <sup>r</sup>			C
$^{125}_{53}\text{I}_{72}$	188	35ns	[3/2]	$\pm 3$					J
$^{126}_{53}\text{I}_{73}$		13d	2						F
$^{127}_{53}\text{I}_{74}$			5/2	+2.8091	153	-0.79 <sup>es</sup>	+0.18		C D E F G
$^{127}_{53}\text{I}_{74}$	58	1.92ns	[7/2]	$\pm 2.2^b$		-0.71 <sup>r</sup>			I J
$^{127}_{53}\text{I}_{74}$	203	330ps	[3/2]	$\geq \pm 1.1$					J
$^{128}_{53}\text{I}_{75}$		25m	1						F
$^{129}_{53}\text{I}_{76}$		16My	7/2	+2.6174	143	-0.55 <sup>r</sup>			C D E
$^{129}_{53}\text{I}_{76}$	27	15ns	[5/2]	+2.8		-0.68 <sup>r</sup>			I
$^{130}_{53}\text{I}_{77}$		12h	5						F
$^{131}_{53}\text{I}_{78}$		8.1d	7/2	+2.738	15	-0.40 <sup>r</sup>			C F
$^{131}_{53}\text{I}_{78}$	150	0.95ns	[5/2]	+2.8					J
$^{131}_{53}\text{I}_{78}$	1797	5.9ns	[9/2]	-0.7					J
			or 11/2]	-0.9					
$^{132}_{53}\text{I}_{79}$		2.3h	4	$\pm 3.08$	2	$\pm 0.08^r$			F
						$\mu/Q$ negative			
$^{132}_{53}\text{I}_{79}$	49.7	0.95ns	[3]	+2.2					J
$^{133}_{53}\text{I}_{80}$		21h	7/2	+2.84	2	-0.26 <sup>r</sup>			F
$^{135}_{53}\text{I}_{82}$		6.7h	7/2						F
$^{129}_{54}\text{Xe}_{75}$			1/2	-0.7768	43				E F G H
$^{129}_{54}\text{Xe}_{75}$	40	700ps	[3/2]			$\pm 0.41^r$			I
$^{131}_{54}\text{Xe}_{77}$			3/2	+0.6908	39	-0.12 <sup>s</sup>	+0.048		E F G
$^{132}_{54}\text{Xe}_{78}$			0 <sup>d</sup>						G
$^{132}_{54}\text{Xe}_{78}$	668	7ps	[2]	+0.9					J
$^{134}_{54}\text{Xe}_{80}$			0 <sup>d</sup>						G
$^{136}_{54}\text{Xe}_{82}$			0 <sup>d</sup>						G
$^{125}_{55}\text{Cs}_{70}$		45m	1/2	+1.41	1				F
$^{127}_{55}\text{Cs}_{72}$		6.2h	1/2	+1.45	1				F
$^{129}_{55}\text{Cs}_{74}$		31h	1/2	+?1.479	8				F
$^{130}_{55}\text{Cs}_{75}$		30m	1	+1.37 or	1				F
				-1.45					
$^{131}_{55}\text{Cs}_{76}$		10d	5/2	+3.54	2	-0.57 <sup>*r</sup>			F H
$^{131}_{55}\text{Cs}_{76}$	133	9.3ns	[5/2]	+2.1					J
$^{132}_{55}\text{Cs}_{77}$		6.2d	2	+2.22	1	+0.47 <sup>*r</sup>			F H
$^{133}_{55}\text{Cs}_{78}$			7/2	+2.5779 <sup>d</sup>	148	-0.0030 <sup>*r</sup>	<100	D E F G H	
				(+2.5788)					
$^{133}_{55}\text{Cs}_{78}$	81	6.31ns	[5/2]	+3.44	2				I J
$^{133}_{55}\text{Cs}_{78}$	160	190ps	[5/2]	+1.5					J
$^{134}_{55}\text{Cs}_{79}$		2.2y	4	+2.989	17	+0.36 <sup>*s</sup>			F H
$^{134}_{55}\text{Cs}_{79}$	11.2	47.0ns	[5]	+3.34	2				J
$^{134}_{55}\text{Cs}_{79}$	137	3.1h	8	+1.096	6				F
$^{135}_{55}\text{Cs}_{80}$		2My	7/2	+2.7280 <sup>d</sup>	156	+0.044 <sup>*r</sup>			F H
				(+2.7289)					
$^{136}_{55}\text{Cs}_{81}$		13d	5	+3.70	2				F
$^{137}_{55}\text{Cs}_{82}$		30y	7/2	+2.8372 <sup>d</sup>	162	+0.045 <sup>*r</sup>			F H
				(+2.8382)					
$^{138}_{55}\text{Cs}_{83}$		32m	3	$\pm 0.5$					F

## Summary of Nuclear Moment Values and Index — Continued

Nucleus	Level (keV)	$T_{1/2}$	$I$ ( $h/2\pi$ )	$\mu$ (nm)	Diam. Corr.	$Q$ (b)	$\Omega$ (nmb)	$Q_4$ ( $b^2$ )	Index
$^{130}_{56}\text{Ba}_{74}$	356	63ps	[2]			+0.3 <sup>b</sup>			K
$^{134}_{56}\text{Ba}_{78}$			0 <sup>d</sup>						G
$^{134}_{56}\text{Ba}_{78}$	605	7ps	[2]			$\sim \pm 0.006?$			J K
$^{134}_{56}\text{Ba}_{78}$			3/2			+0.8365 <sup>d</sup>			D E F G H
$^{135}_{56}\text{Ba}_{79}$						(+0.8372)			
$^{135}_{56}\text{Ba}_{79}^+$			3/2						H
$^{136}_{56}\text{Ba}_{80}$			0 <sup>d</sup>						G
$^{136}_{56}\text{Ba}_{80}$	818	1.5ps	[2]						K
$^{137}_{56}\text{Ba}_{81}$			3/2			+0.9357 <sup>d</sup>			E F G H
$^{137}_{56}\text{Ba}_{81}^+$						(+0.9365)			
$^{137}_{56}\text{Ba}_{81}$	662	2.55m	[11/2]						H
$^{137}_{56}\text{Ba}_{81}$			0 <sup>d</sup>						J
$^{138}_{56}\text{Ba}_{82}$									G
$^{131}_{57}\text{La}_{74}$		59m	3/2						F
$^{132}_{57}\text{La}_{75}$		4.5h	2						F
$^{132}_{57}\text{La}_{75}$	?	25m	6						F
$^{133}_{57}\text{La}_{76}$		4.0h	5/2						F
$^{133}_{57}\text{La}_{76}$	535	49ns	[11/2]	$\pm 8$					J
$^{135}_{57}\text{La}_{78}$		19.4h	5/2						F
$^{136}_{57}\text{La}_{79}$		9.9m	1						F
$^{137}_{57}\text{La}_{80}$		60ky	7/2	+2.69	2	+0.26* <sup>r</sup>			G
$^{138}_{57}\text{La}_{81}$		112Gy	5	+3.704	22	+0.51* <sup>r</sup>			E G
$^{139}_{57}\text{La}_{82}$			7/2	+2.778	17	+0.22* <sup>s</sup>			E F G H
$^{140}_{57}\text{La}_{83}$		40h	3	+0.73		+0.1* <sup>r</sup>			F J
$^{130}_{58}\text{Ce}_{72}$		25m	0 <sup>d</sup>						F
$^{132}_{58}\text{Ce}_{74}$		4.2h	0 <sup>d</sup>						F
$^{133}_{58}\text{Ce}_{75}$		5.4h	9/2						F
$^{133}_{58}\text{Ce}_{75}$	?	97m	1/2						F
$^{134}_{58}\text{Ce}_{76}$		72h	0 <sup>d</sup>						F
$^{135}_{58}\text{Ce}_{77}$		17h	1/2						F
$^{137}_{58}\text{Ce}_{79}$		9.0h	3/2	$\pm 0.7$					F
$^{137}_{58}\text{Ce}_{79}$	255	34.4h	11/2	$\pm 0.69$					J
$^{139}_{58}\text{Ce}_{81}$		140d	3/2	$\pm 0.9$					J
$^{140}_{58}\text{Ce}_{82}$	2083	3.41ns	[4]	+4.3		$\pm 0.40*$			J
$^{141}_{58}\text{Ce}_{83}$		33d	7/2						J
$^{142}_{58}\text{Ce}_{84}$	650	6.2ps	[2]			-0.1			K
$^{143}_{58}\text{Ce}_{85}$		34h	3/2	$\sim \pm 1$					J
$^{133}_{59}\text{Pr}_{74}$		7.5m	5/2						F
$^{134}_{59}\text{Pr}_{75}$		18.5m	2						F
$^{135}_{59}\text{Pr}_{76}$		24m	3/2						F
$^{136}_{59}\text{Pr}_{77}$		13.5m	2						F
$^{137}_{59}\text{Pr}_{78}$		1.28h	5/2						F
$^{138}_{59}\text{Pr}_{79}$	?	2.0h	7						F
$^{139}_{59}\text{Pr}_{80}$		4.5h	5/2						F
$^{140}_{59}\text{Pr}_{81}$		3.4m	1						F
$^{141}_{59}\text{Pr}_{82}$			5/2	+4.16	3	-0.058 <sup>s</sup>			G
$^{142}_{59}\text{Pr}_{83}$		19h	2	-0.24		-0.034 <sup>r</sup>			J
$^{142}_{59}\text{Pr}_{83}$	?		5						F
$^{143}_{59}\text{Pr}_{84}$		14d	7/2						F
$^{143}_{59}\text{Pr}_{84}$	57	4.17ns	[5/2]	+2.8					J
$^{134}_{60}\text{Nd}_{74}$		8m	0 <sup>d</sup>						F
$^{135}_{60}\text{Nd}_{75}$		15m	9/2						F
$^{136}_{60}\text{Nd}_{76}$		55m	0 <sup>d</sup>						F

## Summary of Nuclear Moment Values and Index — Continued

Nucleus	Level (keV)	$T_{1/2}$	$I$ ( $h/2\pi$ )	$\mu$ (nm)	Diam. Corr.	$Q$ (b)	$\Omega$ (nmb)	$Q_4$ ( $b^3$ )	Index
$^{137}_{60}\text{Nd}_{77}$		37m	1/2						F
$^{138}_{60}\text{Nd}_{78}$		5.2h	0+						F
$^{139}_{60}\text{Nd}_{79}$		29.7m	3/2						F
$^{139}_{60}\text{Nd}_{79}$	232	5.5h	11/2						F
$^{140}_{60}\text{Nd}_{80}$		3.4d	0+						F
$^{141}_{60}\text{Nd}_{81}$		2.4h	3/2						F
$^{143}_{60}\text{Nd}_{83}$			7/2	-1.063	7	-0.48 <sup>hs</sup>			B F G
$^{144}_{60}\text{Nd}_{84}$	695	4.2ps	[2]	+0.26		-0.2; -0.6			J K
$^{144}_{60}\text{Nd}_{84}$	1314	90ps	[4]	+0.2					J
$^{145}_{60}\text{Nd}_{85}$			7/2	-0.654	4	-0.25 <sup>hr</sup>			B F G
$^{146}_{60}\text{Nd}_{86}$	454	21ps	[2]	+0.48		-0.7			J K
$^{147}_{60}\text{Nd}_{87}$		11d	5/2	$\pm 0.55$		$\pm 0.7^r$			B F
$^{148}_{60}\text{Nd}_{88}$	300	116ps	[2]	+0.45		$\mu/Q$ negative			J K
$^{149}_{60}\text{Nd}_{89}$		1.9h	5/2	$\pm 0.35$		$\pm 1.0^r$			F
$^{150}_{60}\text{Nd}_{90}$	132	1.52ns	[2]	+0.64		-1.7			J K
$^{150}_{60}\text{Nd}_{90}$	397	55.9ps	[4]	+1.3					J
$^{141}_{61}\text{Pm}_{80}$		20.9m	5/2						F
$^{143}_{61}\text{Pm}_{82}$		265d	[5/2, or 7/2]	$\pm 3.8,$ $\pm 3.9$					J
$^{144}_{61}\text{Pm}_{83}$		360d	[5, or 6]	$\pm 1.7,$ $\pm 1.8$					J
$^{147}_{61}\text{Pm}_{86}$		2.6y	7/2	+2.62	2	+0.7			B F G
$^{147}_{61}\text{Pm}_{86}$	91	2.55ns	[5/2]	+3.4					J
$^{148}_{61}\text{Pm}_{87}$		5.4d	1	+2.0		+0.2			F J
$^{148}_{61}\text{Pm}_{87}$	137	43d	[6]	$\pm 1.8$					J
$^{149}_{61}\text{Pm}_{88}$		53h	7/2	$\pm 3.3$					F J
$^{149}_{61}\text{Pm}_{88}$	114	2.58ns	[5/2]	+2.1					J
$^{149}_{61}\text{Pm}_{88}$	188	3.24ns	[3/2]	+1.6					J
$^{149}_{61}\text{Pm}_{88}$	211	80ps	[5/2]	+2.2					J
$^{149}_{61}\text{Pm}_{88}$	270	2.59ns	[7/2]	+3					J
$^{151}_{61}\text{Pm}_{90}$		28h	5/2	$\pm 1.6$		$\pm 1.9$			F
$^{140}_{62}\text{Sm}_{78}$		15m	0+			$\mu/Q$ positive			F
$^{141}_{62}\text{Sm}_{79}$		11.3m	1/2						F
$^{141}_{62}\text{Sm}_{79}$	?	22.9m	11/2						F
$^{142}_{62}\text{Sm}_{80}$		1.2h	0+						F
$^{143}_{62}\text{Sm}_{81}$		8.8m	3/2						F
$^{145}_{62}\text{Sm}_{83}$		340d	[7/2]	$\pm 0.92$					J
$^{147}_{62}\text{Sm}_{85}$		0.1Ty	7/2	-0.813	6	-0.18 <sup>s</sup>			B F G H
$^{147}_{62}\text{Sm}_{85}$	121	780ps	[5/2]	-0.3					J
$^{147}_{62}\text{Sm}_{85}$	198	1.31ns	[3/2]	-0.28					J
$^{148}_{62}\text{Sm}_{86}$	551	7.35ps	[2]	+0.3		-0.8			J K
$^{149}_{62}\text{Sm}_{87}$			7/2	-0.670	5	+0.052 <sup>r</sup>			B F G
$^{149}_{62}\text{Sm}_{87}$	22	7.6ns	5/2	-0.61		+0.4			I
$^{150}_{62}\text{Sm}_{88}$	334	48ps	[2]	+0.60		-1.3			J K
$^{151}_{62}\text{Sm}_{89}$	105	480ps	[5/2]	+0.5					J
$^{151}_{62}\text{Sm}_{89}$	168	760ps	[3/2]	+0.6					J
$^{152}_{62}\text{Sm}_{90}$	122	1.42ns	[2]	+0.69		-1.8			I J K
$^{152}_{62}\text{Sm}_{90}$	366	57ps	[4]	+1.2					J
$^{153}_{62}\text{Sm}_{91}$		47h	3/2	-0.0217	1	+0.9			F
$^{154}_{62}\text{Sm}_{92}$	82	3.02n	[2]	+0.61					J
$^{154}_{62}\text{Sm}_{92}$	267	165ps	[4]	+1.3					J
$^{154}_{62}\text{Sm}_{92}$	549	23.5ps	[6]	+1.9					J
$^{155}_{62}\text{Sm}_{93}$		24m	3/2			$\pm 0.8^r$			F

## Summary of Nuclear Moment Values and Index — Continued

Nucleus	Level (keV)	$T_{1/2}$	$I$ ( $h/2\pi$ )	$\mu$ (nm)	Diam. Corr.	$Q$ (b)	$\Omega$ (nmb)	$Q_4$ ( $b^2$ )	Index
$^{145}_{63}\text{Eu}_{82}$	625	5.9d	5/2						F
$^{146}_{63}\text{Eu}_{83}$		4.65d	4						F
$^{147}_{63}\text{Eu}_{84}$		22d	5/2						F
$^{147}_{63}\text{Eu}_{84}$		765ns	[11/2]	+6.0					J
$^{148}_{63}\text{Eu}_{85}$		54d	5						F
$^{149}_{63}\text{Eu}_{86}$		93d	5/2						F
$^{149}_{63}\text{Eu}_{86}$		2.43 $\mu$ s	[11/2]	+6.1					J
$^{150}_{63}\text{Eu}_{87}$		12.5h	0 $^\ddagger$						F
$^{151}_{63}\text{Eu}_{88}$			5/2	+3.4631 <sup>b</sup>	240	+1.1 <sup>s</sup>			B F G I
				[+3.466]					
$^{151}_{63}\text{Eu}_{88}$	21.7	9.4ns	7/2	+2.57	2	+1.8 <sup>r</sup>			I
$^{152}_{63}\text{Eu}_{89}$		13y	3	-1.937	13	+3.0 <sup>r</sup>			B F G
$^{152}_{63}\text{Eu}_{89}$	49	9.3h	0 $^\ddagger$						F
$^{153}_{63}\text{Eu}_{90}$			5/2	+1.530	11	+2.8 <sup>r</sup>			B E F G
$^{153}_{63}\text{Eu}_{90}$	97	200ps	[5/2]	+3.2					I
				or -0.5					
$^{153}_{63}\text{Eu}_{90}$	103	3.8ns	[3/2]	+1.5 <sup>b</sup>					I J
$^{154}_{63}\text{Eu}_{91}$		16y	3	$\pm 2.001$	14	+1.9 <sup>r</sup>			G J
$^{155}_{63}\text{Eu}_{92}$	105	400ps	[5/2]	+2.5					J
$^{145}_{64}\text{Gd}_{81}$		22.9m	1/2						F
$^{147}_{64}\text{Gd}_{83}$		38.5h	7/2						F
$^{149}_{64}\text{Gd}_{85}$		9.4d	7/2						F
$^{151}_{64}\text{Gd}_{87}$		120d	7/2						F
$^{152}_{64}\text{Gd}_{88}$	344	29ps	[2]	+1.0					J
$^{153}_{64}\text{Gd}_{89}$		242d	3/2						F
$^{154}_{64}\text{Gd}_{90}$	123	1.18ns	[2]	+0.84	1				J
$^{154}_{64}\text{Gd}_{90}$	371	39ps	[4]						J
$^{155}_{64}\text{Gd}_{91}$			3/2	-0.2584	18	+1.6 <sup>s</sup>	-1.6		B E F G I
$^{155}_{64}\text{Gd}_{91}$	87	6.66ns	5/2	-0.93 <sup>i</sup>	1	$\sim \pm 0.2^r$			I J
$^{155}_{64}\text{Gd}_{91}$	105	1.1ns	3/2	+0.4 <sup>i</sup>		$\sim \pm 1^r$			I J
$^{156}_{64}\text{Gd}_{92}$	89	2.22ns	[2]	+0.72 <sup>i</sup>		$\pm 1.2^r$			I J
$^{156}_{64}\text{Gd}_{92}$	288	115ps	[4]	+1.4					J
$^{156}_{64}\text{Gd}_{92}$	1513	190ps	[4]	+3.1					J
$^{157}_{64}\text{Gd}_{93}$			3/2	-0.3388	24	+1.7 <sup>r</sup>			B F G
$^{157}_{64}\text{Gd}_{93}$	64	460ns	[5/2]			$\pm 3.0^r$			I
$^{158}_{64}\text{Gd}_{94}$	79.5	2.49ns	[2]	+0.73 <sup>i</sup>	1	$\pm 1.3^r$			I J
$^{159}_{64}\text{Gd}_{95}$		18h	3/2	$\pm 0.44$					F J
$^{160}_{64}\text{Gd}_{96}$	75	2.7ns	[2]	+0.63		$\pm 1.3^r$			I J
$^{151}_{65}\text{Tb}_{86}$		18h	1/2						F
$^{152}_{65}\text{Tb}_{87}$		18h	2						F
$^{153}_{65}\text{Tb}_{88}$		2.3d	5/2						F
$^{154}_{65}\text{Tb}_{89}$		21h	0 $^\ddagger$						F
$^{154}_{65}\text{Tb}_{89}$	?	8.5h	3						F
$^{155}_{65}\text{Tb}_{90}$		5.6d	3/2						F
$^{156}_{65}\text{Tb}_{91}$		5.4d	3	$\pm 1.4$		+1.4			F
$^{157}_{65}\text{Tb}_{92}$		>30y	[3/2]	$\pm 2.0$					B
$^{158}_{65}\text{Tb}_{93}$		150y	3	$\pm 1.75$	1	+2.7*			B
$^{159}_{65}\text{Tb}_{94}$			3/2	$\pm 2.008$	14	+1.3*			B F G J
$^{159}_{65}\text{Tb}_{94}$	58	130ps	[5/2]	$\pm 2$					I
$^{160}_{65}\text{Tb}_{95}$		72d	3	$\pm 1.70$	1	+2.3			B F J
$^{161}_{65}\text{Tb}_{96}$		6.9d	3/2						F
$^{151}_{66}\text{Dy}_{85}$		18m	7/2						F
$^{152}_{66}\text{Dy}_{86}$		2.4h	0 $^\ddagger$						F

## Summary of Nuclear Moment Values and Index — Continued

Nucleus	Level (keV)	$T_{1/2}$	$I$ ( $h/2\pi$ )	$\mu$ (nm)	Diam. Corr.	$Q$ (b)	$\Omega$ (nmb)	$Q_4$ ( $b^2$ )	Index
$^{153}_{66}\text{Dy}_{87}$		6.4h	7/2	$\pm 0.7$		$\pm 0.14^*$ $\mu/Q$ positive			F
$^{155}_{66}\text{Dy}_{89}$		10h	3/2	$\pm 0.28$		$\pm 0.9^*$ $\mu/Q$ negative			F J
$^{157}_{66}\text{Dy}_{91}$		8.1h	3/2	$\pm 0.31$		$\pm 1.2^*$ $\mu/Q$ negative			F
$^{158}_{66}\text{Dy}_{92}$	630	?	[6]	$\pm 2.2$					J
$^{159}_{66}\text{Dy}_{93}$		144d	3/2						F I J
$^{160}_{66}\text{Dy}_{94}$	87	2.0ns	[2]	$+0.73$		-2			J
$^{160}_{66}\text{Dy}_{94}$	966	2.2ps	[2]	$+0.4$					I J
$^{161}_{66}\text{Dy}_{95}$			5/2	$-0.482$	3	$+2.4^*\text{s}$ $+2.4^*\text{r}$	$\sim +0.6$	B F	I J
$^{161}_{66}\text{Dy}_{95}$	26	28.4ns	5/2	$+0.67^i$		$+1.3^*\text{r}$			I J
$^{161}_{66}\text{Dy}_{95}$	75	3.4ns	3/2	$-0.38$					I J
$^{162}_{66}\text{Dy}_{96}$	80.7	2.25ns	[2]	$+0.72$					I J
$^{163}_{66}\text{Dy}_{97}$			5/2	$+0.676$	5	$+2.5^*\text{r}$ $-2.0^*\text{r}$	$\sim +0.7$	B E F	I J
$^{164}_{66}\text{Dy}_{98}$	73.3	2.39ns	[2]	$+0.70$		$+3.3^*\text{r}$			F
$^{165}_{66}\text{Dy}_{99}$		2.3h	7/2	$\pm 0.52$					I J
$^{166}_{66}\text{Dy}_{100}$		82h	0*						F F
$^{154}_{67}\text{Ho}_{87}$		12m	1						F
$^{155}_{67}\text{Ho}_{88}$		50m	5/2						F
$^{156}_{67}\text{Ho}_{89}$		55m	1						F
$^{157}_{67}\text{Ho}_{90}$		14m	7/2						F
$^{158}_{67}\text{Ho}_{91}$		11m	5						F
$^{158}_{67}\text{Ho}_{91}$	67	29m	2						F
$^{159}_{67}\text{Ho}_{92}$		33m	7/2						F
$^{160}_{67}\text{Ho}_{93}$		26m	5						F
$^{160}_{67}\text{Ho}_{93}$	60	5.0h	2						F
$^{161}_{67}\text{Ho}_{94}$		2.5h	7/2						F
$^{162}_{67}\text{Ho}_{95}$		15m	1						F
$^{162}_{67}\text{Ho}_{95}$	~100	68m	6						F
$^{164}_{67}\text{Ho}_{97}$		29m	1						F
$^{164}_{67}\text{Ho}_{97}$	~46	38m	6						F
$^{165}_{67}\text{Ho}_{98}$			7/2	$+4.12$	3	$+2.7$	$\sim +0.8$	B F G	J
$^{166}_{67}\text{Ho}_{99}$		27h	0*					F	
$^{166}_{67}\text{Ho}_{99}$	9	1.2ky	[7]	$\pm 4.1$					J
$^{156}_{68}\text{Er}_{88}$	344	47.9ps	[2]	$g_{ave} \sim \pm 0.4$					J
$^{157}_{68}\text{Er}_{89}$	453	7.83ps	[4]						
$^{157}_{68}\text{Er}_{89}$		20m	3/2					F	
$^{158}_{68}\text{Er}_{90}$		2.3h	0*					F	
$^{158}_{68}\text{Er}_{90}$	193	433ps	[2]	$g_{ave} \sim \pm 0.4$					J
$^{160}_{68}\text{Er}_{91}$		356	20.8ps	[4]					
$^{160}_{68}\text{Er}_{91}$		434	4.04ps	[6]					
$^{160}_{68}\text{Er}_{92}$		36m	3/2					F	
$^{160}_{68}\text{Er}_{92}$		29h	0*					F	
$^{160}_{68}\text{Er}_{92}$	264	49.8ps	[4]	$g_{ave} \sim \pm 0.3$					J
$^{160}_{68}\text{Er}_{92}$	376	7.77ps	[6]						
$^{160}_{68}\text{Er}_{92}$	465	4.04ps	[8]						
$^{161}_{68}\text{Er}_{93}$		3.2h	3/2	$-0.369$	3	$+1.2^*$ $+2.2^*$			
$^{163}_{68}\text{Er}_{95}$		75m	5/2	$+0.56$					
$^{164}_{68}\text{Er}_{96}$	92	1.6ns	[2]	$\pm 0.71$		$\pm 2.2^r$			I
$^{165}_{68}\text{Er}_{97}$		10h	5/2	$\pm 0.65$		$\mu/Q$ positive		F	
$^{166}_{68}\text{Er}_{98}$	80.6	1.82ns	[2]	$+0.63$		$-2.0^*$		I J K	
$^{166}_{68}\text{Er}_{98}$	265	120ps	[4]	$+1.2$		$-2.7$		J K	
$^{166}_{68}\text{Er}_{98}$	787	?	[2]			$+2.0$		K	

## Summary of Nuclear Moment Values and Index — Continued

Nucleus	Level (keV)	$T_{1/2}$	$I$ ( $h/2\pi$ )	$\mu$ (nm)	Diam. Corr.	$Q$ (b)	$\Omega$ (nmb)	$Q_4$ ( $b^2$ )	Index
$^{167}_{68}\text{Er}_{99}$			7/2	-0.564	4	+2.83 <sup>s</sup>			B F I J
$^{168}_{68}\text{Er}_{100}$	80	1.91ns	[2]	+0.65		-2			J K
$^{168}_{68}\text{Er}_{100}$	264	120ps	[4]	+1.2					J
$^{168}_{68}\text{Er}_{100}$	~7800	?	[4]	~0					J
$^{168}_{68}\text{Er}_{100}$	~7800	?	[3]	±6					J
$^{169}_{68}\text{Er}_{101}$			9.4d	1/2	4	+0.513			F
$^{170}_{68}\text{Er}_{102}$	79	1.90ns	[2]	+0.64		-2.1*			I J K
$^{170}_{68}\text{Er}_{102}$	261	135ps	[4]	±1.2		-2			J K
$^{171}_{68}\text{Er}_{103}$		7.5h	5/2	±0.70	1	±2.3 <sup>r</sup>			F
						$\mu/Q$ negative			
$^{159}_{69}\text{Tm}_{90}$		9m	5/2						F
$^{160}_{69}\text{Tm}_{91}$		9m	1						F
$^{161}_{69}\text{Tm}_{92}$		37m	7/2						F
$^{162}_{69}\text{Tm}_{93}$		21m	1						F
$^{163}_{69}\text{Tm}_{94}$		1.8h	1/2	±0.08					F
$^{164}_{69}\text{Tm}_{95}$		2m	1						F
$^{164}_{69}\text{Tm}_{95}$	?	5m	6						F
$^{165}_{69}\text{Tm}_{96}$		29h	1/2	±0.138	1				F
$^{166}_{69}\text{Tm}_{97}$		7.7h	2	±0.092	1	±1.9*			F
						$\mu/Q$ positive			
$^{167}_{69}\text{Tm}_{98}$		9.6d	1/2	-0.20					F
$^{168}_{69}\text{Tm}_{99}$		85d	3						F
$^{169}_{69}\text{Tm}_{100}$		1/2							G H
$^{169}_{69}\text{Tm}_{100}$	8.4	4ns	[3/2]	+0.52	2	-1.3*			I
$^{169}_{69}\text{Tm}_{100}$	118	62ps	[5/2]	+0.74	1				J
$^{169}_{69}\text{Tm}_{100}$	139	320ps	[7/2]	+1.30	1	$Q/Q_{118}=1.0$			J
$^{169}_{69}\text{Tm}_{100}$	316	660ns	[7/2]	±0.15					J
$^{169}_{69}\text{Tm}_{100}$	379	36ns	[7/2]	±0.96	1				J
$^{170}_{69}\text{Tm}_{101}$		127d	1	±0.246	2	±0.59			F
						$\mu/Q$ positive			
$^{171}_{69}\text{Tm}_{102}$		1.9y	1/2	±0.229	2				F
$^{171}_{69}\text{Tm}_{102}$	117	55ps	[5/2]	+0.8					J
$^{171}_{69}\text{Tm}_{102}$	129	362ps	[7/2]	+1.2					J
$^{169}_{70}\text{Yb}_{99}$		32d	[7/2]	±0.6					J
$^{170}_{70}\text{Yb}_{100}$	84	1.58ns	[2]	+0.68	1	negative			I J
$^{171}_{70}\text{Yb}_{101}$		1/2		+0.4919 <sup>d</sup>	40				B E G H
				(+0.4930)					
$^{171}_{70}\text{Yb}_{101}$	67	900ps	[3/2]	±0.35					I
$^{171}_{70}\text{Yb}_{101}$	76	2ns	[5/2]	+1.01					I
$^{172}_{70}\text{Yb}_{102}$	78.7	1.6ns	[2]	+0.64 <sup>b</sup>		+3			I J
$^{172}_{70}\text{Yb}_{102}$	260	132ps	[4]			-2			K
$^{172}_{70}\text{Yb}_{102}$	1174	7.95ps	[3]	+0.66	1	±4			J
$^{173}_{70}\text{Yb}_{103}$		5/2		-0.6776 <sup>d</sup>	54	+3.0			B E G H
				(-0.6791)					
$^{173}_{70}\text{Yb}_{103}$	79	38ps	[7/2]	-0.20					J
$^{173}_{70}\text{Yb}_{103}$	179	36ps	[9/2]	~+0.3					J
$^{173}_{70}\text{Yb}_{103}$	351	0.45ns	[11/2]	~-0.7					J
$^{174}_{70}\text{Yb}_{104}$	76.5	1.79ns	[2]	+0.68 <sup>b</sup>	1				I J
$^{174}_{70}\text{Yb}_{104}$	252	?	[4]			-2			K
$^{175}_{70}\text{Yb}_{105}$		4.2d	[7/2]	±0.3 <sup>b</sup>		~±6			J
$^{176}_{70}\text{Yb}_{106}$	82	1.76ns	[2]	+0.76	1				I J
$^{176}_{70}\text{Yb}_{106}$	270	?	[4]			~0			K

## Summary of Nuclear Moment Values and Index — Continued

Nucleus	Level (keV)	$T_{1/2}$	$I$ ( $h/2\pi$ )	$\mu$ (nm)	Diam. Corr.	$Q$ (b)	$\Omega$ (nmb)	$Q_4$ ( $b^2$ )	Index
$^{167}\text{Lu}_{96}$		54m	7/2						F
$^{169}\text{Lu}_{98}$		1.5d	7/2						F
$^{170}\text{Lu}_{99}$		2.0d	0*						F
$^{171}\text{Lu}_{100}$		8.3d	7/2						F
$^{175}\text{Lu}_{104}$			7/2	+2.230	18	+5.6 <sup>s</sup>			E F G H
$^{175}\text{Lu}_{104}$	114	100ps	[9/2]	+1.9					J
$^{175}\text{Lu}_{104}$		251	[11/2]	+1.9					J
$^{176}\text{Lu}_{105}$		20Gy	7	+3.18	3	+8.0 <sup>r</sup>			F G
$^{176}\text{Lu}_{105}$	~300	3.7h	1	+0.318	3	-2.3 <sup>r</sup>			F
$^{177}\text{Lu}_{106}$		6.8d	7/2	+2.24	2	+5.4 <sup>r</sup>			F
$^{177}\text{Lu}_{106}$	971	155d	[23/2]			+13			J
$^{176}\text{Hf}_{104}$	88.4	1.40ns	[2]	+0.53					J
$^{177}\text{Hf}_{105}$			7/2	+0.7902	66	+4.5*			F G
$^{177}\text{Hf}_{105}$	113	500ps	[9/2]	+1.12	1				J
$^{177}\text{Hf}_{105}$	250	55ps	[11/2]	+2.6					J
$^{177}\text{Hf}_{105}$	321	660ps	[9/2]	-0.51					J
$^{178}\text{Hf}_{106}$			0*						G
$^{178}\text{Hf}_{106}$	93	1.50ns	[2]	+0.58 <sup>b</sup>					I J
$^{179}\text{Hf}_{107}$			9/2	-0.638	5	+5.1*			F G
$^{180}\text{Hf}_{108}$			0*						G
$^{180}\text{Hf}_{108}$	93	1.50ns	[2]	+0.64 <sup>b</sup>					J
$^{180}\text{Hf}_{108}$	309	71ps	[4]	+2.3					J
$^{181}\text{Ta}_{108}$			7/2	+2.35	2	+3* <sup>s</sup>			E F G
$^{181}\text{Ta}_{108}$	6.2	6.8μs	[9/2]	+5.1		+3* <sup>r</sup>			I
$^{181}\text{Ta}_{108}$	482	10.8ns	[5/2]	+3.29	3	positive			H J
$^{182}\text{Ta}_{109}$		115d	[3]	±2.6					J
$^{183}\text{Ta}_{110}$		5.0d	7/2						F
$^{182}\text{W}_{108}$			0*						G
$^{182}\text{W}_{108}$	100	1.37ns	[2]	+0.51					I J
$^{182}\text{W}_{108}$	329	64ps	[4]	+0.7					J
$^{182}\text{W}_{108}$	1289	1.04ns	[2]	+1.4					J
$^{182}\text{W}_{108}$	1374	2.25ns	[3]	±0.10					J
$^{183}\text{W}_{109}$			1/2	+0.1169	10				E G
$^{183}\text{W}_{109}$	46	180ps	[3/2]	-0.1					I
$^{183}\text{W}_{109}$	99	700ps	[5/2]	+0.7					I J
$^{184}\text{W}_{110}$			0*						G
$^{184}\text{W}_{110}$	111	1.26ns	[2]	+0.56					I J
$^{184}\text{W}_{110}$	364	43.5ps	[4]	+1.2					J
$^{185}\text{W}_{111}$		74d	3/2						F
$^{186}\text{W}_{112}$			0*						G
$^{186}\text{W}_{112}$	123	1.01ns	[2]	+0.65	1				I J
$^{186}\text{W}_{112}$	399	25ps	[4]	+0.8		-3			J K
$^{186}\text{W}_{112}$	730	4.2ps	[2]			+0.7			K
$^{187}\text{W}_{113}$		24h	3/2						F
$^{183}\text{Re}_{108}$		70d	[5/2]	±3.1					J
$^{183}\text{Re}_{108}$	496	7.89ns	[9/2]	±5.3					J
$^{184}\text{Re}_{109}$		38d	[3]	±2.5					J
$^{184}\text{Re}_{109}$	188	165d	[8]	±2.9					J
$^{185}\text{Re}_{110}$			5/2	+3.172	28	+2.3 <sup>r</sup>			C D E G
$^{186}\text{Re}_{111}$		90h	1	+1.73	1	~±0.4 <sup>r</sup>			F G
$^{187}\text{Re}_{112}$		60Gy	5/2	+3.204	28	+2.2 <sup>s</sup>			C E G
$^{187}\text{Re}_{112}$	206	560ns	[9/2]	+4.8					J
$^{188}\text{Re}_{113}$		17h	1	+1.78	1	~±0.4 <sup>r</sup>			F G

## Summary of Nuclear Moment Values and Index — Continued

Nucleus	Level (keV)	$T_{1/2}$	$I$ ( $h/2\pi$ )	$\mu$ (nm)	Diam. Corr.	$Q$ (b)	$\Omega$ (nmb)	$Q_4$ ( $b^2$ )	Index
$^{184}_{76}\text{Os}_{108}$	?	?	[2]			-2			K
$^{186}_{76}\text{Os}_{110}$	137	840ps	[2]	+0.61	1	+1.5			J K
$^{187}_{76}\text{Os}_{111}$			1/2	+0.0643	6				E G
$^{188}_{76}\text{Os}_{112}$	155	710ps	[2]	+0.55		-0.4; -1.3			J K
$^{188}_{76}\text{Os}_{112}$	633	5.6ps	[2]	+0.9					J
$^{189}_{76}\text{Os}_{113}$			3/2	+0.6565	59	+0.8*			E G
$^{190}_{76}\text{Os}_{114}$	187	350ps	[2]	+0.68	1	+0.3; -1.0			J K
$^{190}_{76}\text{Os}_{114}$	548	28ps	[4]	+0.9					J
$^{192}_{76}\text{Os}_{116}$	206	280ps	[2]	+0.78	1	+1.2; -0.4			J K
$^{192}_{76}\text{Os}_{116}$	489	28ps	[2]	$\pm 0.7$					J
$^{191}_{77}\text{Ir}_{114}$			3/2	+0.1454	14	+1.1*			
$^{191}_{77}\text{Ir}_{114}$	82	3.8ns	[1/2]	+0.546	5				I
$^{191}_{77}\text{Ir}_{114}$	129	131ps	[5/2]	+0.5					J
$^{191}_{77}\text{Ir}_{114}$	171	4.9s	[11/2]	$\pm 6.1$	1				E J
$^{192}_{77}\text{Ir}_{115}$		74d	4	+1.90	2				E F J
$^{193}_{77}\text{Ir}_{116}$			3/2	+0.1583	15	+1.0*			B E F G I
$^{193}_{77}\text{Ir}_{116}$	73	6.2ns	1/2	+0.468	4				J
$^{193}_{77}\text{Ir}_{116}$	139	90ps	[5/2]	+0.6					F J
$^{194}_{77}\text{Ir}_{117}$		17h	1	$\pm 0.37$					
$^{192}_{78}\text{Pt}_{114}$	316	35ps	[2]	+0.93 <sup>1</sup>	1				J
$^{192}_{78}\text{Pt}_{114}$	612	20ps	[2]	+1.0 <sup>k</sup>					J
$^{192}_{78}\text{Pt}_{114}$	785	12ps	[4]	$\pm 0.9^k$					J
$^{194}_{78}\text{Pt}_{116}$			0*						G
$^{194}_{78}\text{Pt}_{116}$	328	35ps	[2]	+0.6		+0.6; +0.9			J K
$^{194}_{78}\text{Pt}_{116}$	622	44ps	[2]	+0.4					J
$^{195}_{78}\text{Pt}_{117}$			1/2	+0.6022	56				E F G
$^{195}_{78}\text{Pt}_{117}$	99	160ps	[3/2]	-0.60	1				I
$^{195}_{78}\text{Pt}_{117}$	210	67ps	[3/2]	+0.3					J
$^{195}_{78}\text{Pt}_{117}$	240	230ps	[5/2]	+0.22					J
$^{195}_{78}\text{Pt}_{117}$	259	4.1d	[13/2]	$\pm 0.60$	1				E J
$^{196}_{78}\text{Pt}_{118}$			0*						G
$^{196}_{78}\text{Pt}_{118}$	356	35ps	[2]	+0.55		+0.5; +0.6			J K
$^{197}_{78}\text{Pt}_{119}$		20h	1/2	$\pm 0.5^p$					F
$^{198}_{78}\text{Pt}_{120}$	408	19ps	[2]	+0.5		+1.2			J K
$^{190}_{79}\text{Au}_{111}$		40m	1	$\pm 0.066$	1				F
$^{191}_{79}\text{Au}_{112}$		3.0h	3/2	$\pm 0.137$	1				F
$^{192}_{79}\text{Au}_{113}$		4.1h	1	$\pm 0.0079$	1				F
$^{193}_{79}\text{Au}_{114}$		18h	3/2	$\pm 0.139$	1				F
$^{194}_{79}\text{Au}_{115}$		39h	1	$\pm 0.074$	1				F
$^{195}_{79}\text{Au}_{116}$		192d	3/2	$\pm 0.147$	1				F J
$^{196}_{79}\text{Au}_{117}$		6.2d	2	+0.588	6				F
$^{196}_{79}\text{Au}_{117}$	596	9.7h	12	$\pm 5.4$					F J
$^{197}_{79}\text{Au}_{118}$			3/2	+0.14486	137	+0.59	$\sim +0.01$		B E F G H I
$^{197}_{79}\text{Au}_{118}$	77	1.9ns	[1/2]	+0.42					F
$^{198}_{79}\text{Au}_{119}$		2.7d	2	+0.590	6				J
$^{198}_{79}\text{Au}_{119}$	367	123ns	[3]	$\pm 3.6$					J
$^{198}_{79}\text{Au}_{119}$	?	49h	[12?]	$\pm 5.6$	1				J
$^{199}_{79}\text{Au}_{120}$		3.2d	3/2	+0.270	3				F
$^{200}_{79}\text{Au}_{121}$	?	18.7h	[12]	$\pm 6.1$	1				E J
$^{183}_{80}\text{Hg}_{103}$		8.8s	1/2	+0.52					E H J
$^{185}_{80}\text{Hg}_{105}$		50s	1/2	+0.50					E H J
$^{187}_{80}\text{Hg}_{107}$		2.4m	3/2	-0.59	1	-0.3			H J

## Summary of Nuclear Moment Values and Index — Continued

Nucleus	Level (keV)	$T_{1/2}$	$I$ ( $h/2\pi$ )	$\mu$ (nm)	Diam. Corr.	$Q$ (b)	$\Omega$ (nmb)	$Q_4$ ( $b^2$ )	Index
$^{193}_{80}\text{Hg}_{113}$		6h	3/2	-0.6236	60	-1 <sup>r</sup>			G H
$^{193}_{80}\text{Hg}_{113}$	140	11h	13/2	-1.052	10	+1.2 <sup>r</sup>			G H
$^{195}_{80}\text{Hg}_{115}$		9.5h	1/2	+0.538	5				G H
$^{195}_{80}\text{Hg}_{115}$	176	40h	13/2	-1.038	10	+1.2 <sup>r</sup>			G H
$^{197}_{80}\text{Hg}_{117}$		65h	1/2	+0.5241	51				G H
$^{197}_{80}\text{Hg}_{117}$	134	7.3ns	[5/2]	+0.96	1				J
$^{197}_{80}\text{Hg}_{117}$	299	24h	13/2	-1.0214	99	+1.4 <sup>r</sup>			G H
$^{198}_{80}\text{Hg}_{118}$		0 <sup>d</sup>							G
$^{198}_{80}\text{Hg}_{118}$	412	22.0ps	[2]	+1.1					J
$^{199}_{80}\text{Hg}_{119}$			1/2	+0.50271 <sup>d</sup>	485				G
				(+0.50415)					
$^{199}_{80}\text{Hg}_{119}$	158	2.32ns	[5/2]	+1.0		±0.7			J
$^{199}_{80}\text{Hg}_{119}$	533	44m	13/2	±1.0083	97	+2			H J
$^{200}_{80}\text{Hg}_{120}$		0 <sup>d</sup>							G
$^{200}_{80}\text{Hg}_{120}$	368	42ps	[2]	+0.9					J
$^{201}_{80}\text{Hg}_{121}$			3/2	-0.55671 <sup>d</sup>	537	+0.44 <sup>s</sup>	-0.13		D E F G H
				(-0.55830)					
$^{202}_{80}\text{Hg}_{122}$		0 <sup>d</sup>							G
$^{202}_{80}\text{Hg}_{122}$	439	26ps	[2]	+1.2					J
$^{203}_{80}\text{Hg}_{123}$		47d	5/2	+0.86	1	+0.5			G H
$^{204}_{80}\text{Hg}_{124}$		0 <sup>d</sup>							G
$^{204}_{80}\text{Hg}_{124}$	437	46ps	[2]	+0.8					J
$^{205}_{80}\text{Hg}_{115}$		5.5m	1/2	+0.597	6				H J
$^{193}_{81}\text{Tl}_{112}$		23m	1/2						F
$^{194}_{81}\text{Tl}_{113}$		33m	2	±0.135	1				F
$^{195}_{81}\text{Tl}_{114}$		1.2h	1/2	+1.57	2				F G
$^{196}_{81}\text{Tl}_{115}$		1.8h	2	±0.0699	7				F
$^{197}_{81}\text{Tl}_{116}$		2.7h	1/2	+1.56	2				F G
$^{198}_{81}\text{Tl}_{117}$		5.3h	2	±0.00121	1				F
$^{198}_{81}\text{Tl}_{117}$	544	1.8h	7	±0.64	1				F
$^{199}_{81}\text{Tl}_{118}$		7.4h	1/2	+1.62	2				F G
$^{200}_{81}\text{Tl}_{119}$		26h	2	±0.03568	35				F G
$^{201}_{81}\text{Tl}_{120}$		72h	1/2	+1.65	2				F G
$^{202}_{81}\text{Tl}_{121}$		12d	2	±0.0565	6				F G
$^{202}_{81}\text{Tl}_{121}$	950	560μs	[7]	±0.90	1				J
$^{203}_{81}\text{Tl}_{122}$			1/2	+1.6115	158				E F G H
$^{203}_{81}\text{Tl}_{122}$	279	280ps	[3/2]	+0.16					J
$^{204}_{81}\text{Tl}_{123}$		3.9y	2	±0.089	1				F
$^{205}_{81}\text{Tl}_{124}$			1/2	+1.6274	160				E F G H
$^{206}_{81}\text{Tl}_{125}$		4.2m	0 <sup>d</sup>						F
$^{204}_{82}\text{Pb}_{122}$	1274	260ns	[4]	+0.22		±0.3			J
$^{205}_{82}\text{Pb}_{123}$	1014	5.55ns	[13/2]	-0.98	1				J
$^{206}_{82}\text{Pb}_{124}$		0 <sup>d</sup>							G
$^{206}_{82}\text{Pb}_{124}$	803	6ps	[2]	~0					J
$^{206}_{82}\text{Pb}_{124}$	2200	123μs	[7]	-0.152	1				J
$^{206}_{82}\text{Pb}_{124}$	2385	29ps	[6]	+0.8					J
$^{206}_{82}\text{Pb}_{124}$	4027	200ns	[12]	-1.86	2				J
$^{207}_{82}\text{Pb}_{125}$			1/2	+0.5783 <sup>d</sup>	58				E F G H
				(+0.5881)					
$^{207}_{82}\text{Pb}_{125}$	570	129ps	[5/2]	+0.8					J
$^{208}_{82}\text{Pb}_{126}$		0 <sup>d</sup>							G
$^{208}_{82}\text{Pb}_{126}$	2615	15ps	[3]	+1.8		-1.1			J K
$^{208}_{82}\text{Pb}_{126}$	3198	298ps	[5]	+0.10					J

## Summary of Nuclear Moment Values and Index — Continued

Nucleus	Level (keV)	$T_{1/2}$	$I$ ( $h/2\pi$ )	$\mu$ (nm)	Diam. Corr.	$Q$ (b)	$\Omega$ (nmb)	$Q_4$ ( $b^2$ )	Index
$^{199}_{83}\text{Bi}_{116}$		25m	9/2						F
$^{200}_{83}\text{Bi}_{117}$		35m	7						F
$^{201}_{83}\text{Bi}_{118}$		1.8h	9/2						F
$^{202}_{83}\text{Bi}_{119}$		1.6h	5						F
$^{203}_{83}\text{Bi}_{120}$		12h	9/2	+4.59	5	-0.71 <sup>r</sup>			F
$^{204}_{83}\text{Bi}_{121}$		12h	6	+4.25	4	-0.46 <sup>r</sup>			F
$^{205}_{83}\text{Bi}_{122}$		15d	9/2	~+5.5					F
$^{206}_{83}\text{Bi}_{123}$		6.3d	6	+4.56	5	-0.21 <sup>r</sup>			F G
$^{207}_{83}\text{Bi}_{124}$	2102	182 $\mu$ s	[21/2]	+3.4					J
$^{209}_{83}\text{Bi}_{126}$		>2Ay	9/2	+4.080	41	-0.38 <sup>s</sup>	+0.5		D E F G
$^{210}_{83}\text{Bi}_{127}$		5d	1	-0.0442	4	+0.14 <sup>r</sup>			F
$^{211}_{83}\text{Bi}_{128}$	405	318ps	[7/2]	+4.4					J
$^{201}_{84}\text{Po}_{117}$		18m	3/2						F
$^{202}_{84}\text{Po}_{118}$		51m	0 <sup>d</sup>						F
$^{203}_{84}\text{Po}_{119}$		42m	5/2						F
$^{204}_{84}\text{Po}_{120}$		3.5h	0 <sup>d</sup>						F
$^{204}_{84}\text{Po}_{120}$	~1700	140ns	[8]	±7.8	1				J
$^{205}_{84}\text{Po}_{121}$		1.8h	5/2	≈+0.26		+0.17			F
$^{206}_{84}\text{Po}_{122}$		8.8d	0 <sup>d</sup>						F
$^{206}_{84}\text{Po}_{122}$	?	212ns	[8]	±7.4	1				J
$^{207}_{84}\text{Po}_{123}$		6.0h	5/2	≈+0.27		+0.28	+0.11		F
$^{207}_{84}\text{Po}_{123}$	1115	47 $\mu$ s	[13/2]	-0.93	1				J
$^{208}_{84}\text{Po}_{124}$	1530	380ns	[8]	±7.3	1				J
$^{209}_{84}\text{Po}_{125}$		103y	1/2	+0.77	1				G
$^{209}_{84}\text{Po}_{125}$	>1327	~100ns	[17/2?]	+7.5	1				J
$^{210}_{84}\text{Po}_{126}$		138d	0 <sup>d</sup>						F
$^{210}_{84}\text{Po}_{126}$	1472	38ns	[6]	±5.6	1				J
$^{210}_{84}\text{Po}_{126}$	1552	110ns	[8]	+7.3	1				J
$^{210}_{84}\text{Po}_{126}$	~2800	24ns	[11]	+12.0	1				J
$^{210}_{84}\text{Po}_{126}$	4372	93ns	[13]	±7.1	1				J
$^{211}_{84}\text{Po}_{127}$	1064	16ns	[15/2]	±0.4					J
$^{211}_{85}\text{At}_{126}$		7.2h	9/2						F
$^{211}_{85}\text{At}_{126}$	1416	50ns	[21/2]	±9.4	1				J
$^{211}_{85}\text{At}_{126}$	4816	4.2 $\mu$ s	[39/2]	±14					J
			or 41/2]	±15					
$^{212}_{86}\text{Rn}_{126}$	~1700	1.0 $\mu$ s	[8]	±7.2	1				J
$^{222}_{86}\text{Rn}_{136}$	186	320ps	[2]	+0.9					J
$^{223}_{88}\text{Ra}_{135}$	50	630ps	[3/2]	+0.42					J
$^{227}_{89}\text{Ac}_{138}$		22y	3/2	+1.1		+1.7			G
$^{229}_{90}\text{Th}_{139}$		7.3ky	5/2	+0.38		~+4.6			G
$^{231}_{91}\text{Pa}_{140}$		34ky	3/2	±1.98	2				B G
$^{233}_{91}\text{Pa}_{142}$		27d	3/2	+3.4		-3.0			F
$^{233}_{92}\text{U}_{141}$		162ky	5/2	+0.64	1	+4.2 <sup>s</sup>			B G J
$^{235}_{92}\text{U}_{143}$		710My	7/2	-0.43		+4.9 <sup>r</sup>			B G J

## Summary of Nuclear Moment Values and Index — Continued

Nucleus	Level (keV)	$T_{1/2}$	$I$ ( $h/2\pi$ )	$\mu$ (nm)	Diam. Corr.	$Q$ (b)	$\Omega$ (nmb)	$Q_4$ ( $b^2$ )	Index
$^{237}_{93}\text{Np}_{144}$		2.1My	5/2	+2.4 <sup>l</sup>		positive			G J
$^{237}_{93}\text{Np}_{144}$	60	63ns	[5/2]	+1.3 <sup>k</sup>		$Q/Q_{gs} = +1.0$			I J
$^{238}_{93}\text{Np}_{145}$		2.1d	2						F
$^{239}_{93}\text{Np}_{146}$		2.3d	5/2						F
$^{239}_{93}\text{Np}_{146}$	75	1.40ns	[5/2]	+1.3 <sup>k</sup>					J
$^{239}_{94}\text{Pu}_{145}$		24ky	1/2	+0.200 <sup>l</sup>	2				B F G
$^{241}_{94}\text{Pu}_{147}$		13y	5/2	-0.68 <sup>k</sup>	1	+5.6			B G
$^{241}_{95}\text{Am}_{146}$		460y	5/2	+1.59	2	+4.9			B F G
$^{242}_{95}\text{Am}_{147}$		16h	1	+0.383	5	-2.8			F
$^{243}_{95}\text{Am}_{148}$		8ky	5/2	+1.59	2	+4.9			G
$^{242}_{96}\text{Cm}_{146}$		160d	0 <sup>+</sup>						F
$^{243}_{96}\text{Cm}_{147}$		28y	5/2	$\pm 0.4$					B
$^{245}_{96}\text{Cm}_{149}$		8.26ky	7/2	$\pm 0.5$					B
$^{247}_{96}\text{Cm}_{151}$		15.4My	9/2	$\pm 0.4$					B
$^{249}_{97}\text{Bk}_{152}$		314d	7/2	$\pm 5$		$\pm 5$			G
$^{253}_{99}\text{Es}_{154}$		20.5d	7/2	+4.0		+6			B F G J

<sup>l</sup> No hyperfine structure observed<sup>\*</sup> Polarization or Sternheimer corrections included<sup>a</sup> Weighted average<sup>b</sup> Wide spread in tabulated values<sup>c</sup> Atomic beam value of [59St46] adopted<sup>d</sup> OP and NMR values discrepant. Values in ( )'s based on NMR values<sup>e</sup> ENDOR and NMR values discrepant. Values in ( )'s based on NMR values<sup>f</sup> ABMR and NMR values discrepant. Values in ( )'s based on NMR values<sup>g</sup> No diamagnetic correction added. Not certain of corrections used by authors or if corrected.<sup>h</sup> ABMR and ENDOR values discrepant. Values in [ ]'s based on ENDOR values<sup>i</sup> Mössbauer and PAC values discrepant<sup>j</sup> In the latest adjustment of fundamental constants [73CoTa], this value has been increased to 2.7928456 11.<sup>k</sup> Relative value calculated from  $\mu$ -ratio and  $\mu^1$ <sup>l</sup> Summary value upon which relative  $\mu$ -values depend<sup>p</sup> Preliminary value from meeting abstract, report, thesis or private communication<sup>r</sup> Relative value calculated from  $Q$ -ratio and  $Q^s$ <sup>s</sup> Summary value, average of tabulated values unless otherwise marked

## 5. Tables of Nuclear Moment Data

**Table A: Neutron, Proton, and Anti-Proton Moments**

### Introduction

Since the methods used for the measurement of the moments of the proton, anti-proton, and neutron differ appreciably from those used for other particles, the available information is incorporated into a separate table. All methods involve an application of the principle of magnetic resonance.

Consider a particle with a spin quantum number  $s=1/2$  with an associated magnetic dipole moment  $\mu$  in a magnetic field  $H$ . The particle will become oriented in one of two possible states characterized by the magnetic quantum number  $m=+1/2$  and  $m=-1/2$ . The behavior of the particle may be described semi-classically by saying that the spin vector precesses about  $H$  with a rotational frequency  $\nu$  (Larmor frequency)

$$\nu = \gamma H / 2\pi,$$

where the gyromagnetic ratio of the particle is  $\gamma = 2\pi\mu/sh$ .

If, now, we introduce a weak magnetic field  $H_1$  perpendicular to  $H$  and rotating about it with frequency  $\nu$ ,  $s$  will be forced to precess about  $H_1$  as well as  $H$  and the particle will slowly change from the  $m=+1/2$  to the  $-1/2$  state and vice versa. It is this resonance between the applied rotation frequency of  $H_1$  and the Larmor frequency of the particle that constitutes magnetic resonance.

Since the frequency can be measured with very high accuracy, the limitation in the determination of  $\mu$  lies in the difficulty of measuring the field  $H$ . Absolute measurement of magnetic field is extremely difficult. Two alternate procedures have been adopted for the proton:

- (1) The ratio of the proton precession frequency to the cyclotron frequency of either the free electron or the free proton is measured. The first yields

the magnetic moment in terms of  $eh/4\pi mc$ , the Bohr magneton; the second, the moment in terms of the nuclear magneton,  $eh/4\pi M_p c$ .

- (2) The proton precession frequency is measured in terms of the standard ampere which may be expressed in units of length, mass and time.

In computing the magnetic moment of the proton in nuclear magnetons from the measured quantities, the following conversion factors based on the fundamental constants in [69TaPa] have been used:

$$\gamma_p (\text{in rad}\cdot\text{s}^{-1}\cdot\text{T}^{-1}) \times (1.043953 \text{ I0}) \times 10^{-8} = \mu_p (\text{in nm}),$$

$$\mu_p (\text{in Bohr magnetons}) \times (1836.109 \text{ II}) = \mu_p (\text{in nm}).$$

Total diamagnetic corrections of +0.000073 nm for water samples or +0.000079 nm for oil samples, as given in [50Th06], have been added to the uncorrected proton moments. The uncertainties quoted in the table include the uncertainties in the conversion factors used.

Detailed descriptions of the techniques and measurements can be found in the original papers and in Laukien [58La04]. There is a good discussion of the various experiments for the measurement of the proton moment and their sources of error in Taylor, Parker and Langenberg's article on *The Fundamental Constants and Quantum Electrodynamics* [69TaPa] as well as in the earlier papers by Cohen and Dumond [66Co36, 65Co20].

The neutron magnetic moment is measured by passing a beam of polarized neutrons through a strong magnetic field and inducing a magnetic transition with a resonant rotating magnetic field. This transition causes a reversal of the polarization with a consequent decrease in the neutron intensity at the polarization analyzer-detector. The change in intensity serves to indicate the resonance condition. The uniform magnetic field is measured by a point-to-point determination of the proton precession frequency. This procedure yields a value of  $\mu_n/\mu_p$  subject to the correction for the chemical form of the hydrogen in the resonance probe.

The last systematic literature search for information included in the table was in early 1971.

### Explanation of Table A

<i>I</i>	Nuclear spin, in units of $h/2\pi$
$\mu$	Nuclear magnetic dipole moment, in nuclear magnetons, given with diamagnetic correction
Refer.	Reference key
Quantity Measured	Directly measured frequency ratio, magnetic moment, or gyromagnetic ratio in appropriate units These values are given without diamagnetic correction unless otherwise indicated.
Method (Compound)	Method by which frequency ratio, moment, or gyromagnetic ratio was measured Compound used for measurement

Table A: Neutron, Proton, and Anti-Proton Moments

I	$\mu$	Refer.	Quantity Measured	Method (Compound)
<b>Neutron</b>				
1/2		37S09		Slow neutron scattering from ortho- and para- $H_2$
	-2 1	38P08		Non-adiabatic transitions in a rotating magnetic field
	$\pm 1.913002\ 80$	48B29	$\omega_n/\omega_p = 0.685001\ 30$	Neutron beam resonance; NMR ( $H_2O$ )
1/2		50H67		Reflection from magnetized iron
	negative	50S88	$\mu_p/\mu_n$ negative	Neutron beam resonance; NMR ( $H_2O$ )
1/2		54S90		Neutron beam resonance
	-1.913159 47	56C57	$\omega_n/\omega_p = 0.685057\ 17$	Neutron beam resonance and proton resonance over same field ( $H_2O$ )
<b>Proton</b>				
1/2		27D01		Specific heat
1/2		29M01		Band spectra
1/2		30H02		Band spectra
	+2.785 2	39K12		Molecular beam magnetic resonance ( $H_2, HD$ )
	$\pm 2.79283\ 11$	49T01	$g/g_J(Cs, ^2S_{1/2}) = 15.1911 \times 10^{-4}$ $g/g_J(In, ^2P_{1/2}) = 45.6877 \times 10^{-4}$ $\mu_p = (15.2106^* 6) 10^{-4} \mu_B$	Atomic and molecular beam magnetic resonance ( $NaOH$ )
	$\pm 2.79249\ 20$	50B73 51J10	$\omega_p/\omega_{cyc} = 2.79242\ 20$	NMR ( $H_2O$ ); decelerating cyclotron
	positive	50S88		NMR ( $H_2O$ )
	$\pm 2.79288\ 6$	50T07	$\gamma_p = (2.67523 6) 10^8 r \cdot s^{-1} T^{-1}$	NMR in magnetic field determined by force
	$\pm 2.79292\ 6$	(65Co20)	$\gamma_p = (2.67534^* 6) 10^8 r \cdot s^{-1} T^{-1}$	on straight wire carrying known current ( $H_2O$ );
	$\pm 2.79292\ 7$	(65Hu13)	$\gamma_p = (2.67527^c 6) 10^8 r \cdot s^{-1} T^{-1}$	strong field measurement
	$\pm 2.79291\ 4$	(69TaPa)	$\gamma_p = (2.675231^{th} 26) 10^8 r \cdot s^{-1} T^{-1}$	
	$\pm 2.79274\ 4$	51G31	$\omega_e/\omega_p = 657.475\ 8$ $\mu_p = (15.20970 18) 10^{-4} \mu_B$	NMR (oil); measured cyclotron frequency of free electrons
	$\pm 2.79275\ 4$	(69TaPa)	$\mu_p = (15.21016^* 19) 10^{-4} \mu_B$	
		52K32	$g_J(H, ^2S_{1/2})/g_p = 658.2171\ 6$	ABMR and NMR (oil) in same field
	$\pm 2.792787\ 17$	(69TaPa)	$\mu_p = (15.210355^* 13) 10^{-4} \mu_B$	
	$\pm 2.792764\ 60$	51S34	$\omega_p/\omega_{cyc} = 2.792685\ 60$	NMR (oil); omegatron
	$\pm 2.792763\ 60$	(69TaPa)	$\omega_p/\omega_{cyc} = 2.792690^t 60$	
		54Bell	$g_J(H)/g = 658.21734\ 19$	
	$\pm 2.792784\ 17$	(69TaPa)	$\mu_p = (15.2103347^* 65) 10^{-4} \mu_B$	Mic; NMR (cylinder of oil)

Table A: Neutron, Proton, and Anti-Proton Moments — Continued

I	$\mu$	Refer.	Quantity Measured	Method (Compound)
	$\pm 2.79281\ 4$	55C36	$\omega_p/\omega_{cyc} = 2.79273\ 4$	NMR ( $H_2O$ ); decelerating cyclotron
	$\pm 2.79275\ 10$	56T19	$\omega_p/\omega_{cyc} = 2.792675\ 100$	NMR ( $H_2O + FeCl_3$ ); decelerating cyclotron
	$\pm 2.79315\ 8$	56W41	$\gamma_p = (2.67549\ 8)10^8 r \cdot s^{-1} T^{-1}$	NMR in a field determined by the dimensions of and current in an iron-free coil ( $H_2O$ )
	$\pm 2.792788\ 17$	57G89 (69TaPa)	$g_J(D)/g = 658.2162\ 8$ $\mu_p = (15.210360^{+1.23})10^{-4} \mu_B$	Mic; NMR (cylinder of oil)
	$\pm 2.79277\ 3$	58Dr05	$\gamma_p = (2.67513\ 2)10^8 r \cdot s^{-1} T^{-1}$	Free precession in the field of a standard solenoid ( $H_2O$ )
	$\pm 2.79277\ 2$	(65Co20)	$\gamma_p = (2.675192^{+0.8})10^8 r \cdot s^{-1} T^{-1}$	See 68Dr06 below
	$\pm 2.79278\ 2$	(65Hu13)	$\gamma_p = (2.675137^{+0.11})10^8 r \cdot s^{-1} T^{-1}$	
	$\pm 2.79277\ 3$	59H32 (69TaPa)	$\omega_e/\omega_p = 657.4501$ $\mu_p = (15.210280^{+1.12})10^{-4} \mu_B$	NMR ( $H_2$ )
	$\pm 2.792781\ 17$	59L15 (69TaPa)	$g_J(H)/g = 658.215909^{+4.44}$ $\mu_p = (15.2099284^{+0.10})10^{-4} \mu_B$	Mic ( $H + H_2 + $ buffer gas)
	$\pm 2.79280\ 2$	59L54	$\omega_e/\omega_p = 657.462\ 3$	NMR (oil); measured cyclotron frequency of free electrons
	$\pm 2.79281\ 2$	(69TaPa)	$\mu_p = (15.21000\ 7)10^{-4} \mu_B$ $\omega_e/\omega_p = 657.4620\ 45$ $\mu_p = (15.21046^{+0.10})10^{-4} \mu_B$	
	$\pm 2.79290\ 6$	61Boll	$\omega_{cyc}(H_2^+)/\omega_d = 1.65957\ 28$ $\omega_p/\omega_d = 6.514411\ 3$	cyclotron frequency of $H_2^+$ and NMR ( $D_2O + CuCl_2 \cdot 2H_2O$ ) in same field; NMR ( $D_2O + CuCl_2 \cdot 2H_2O$ ; $H_2O + CuCl_2$ ) Used $M_p/M(H_2^+) = 0.49986388\ 50$
	$\pm 2.79288\ 10$	61Ca20	$\gamma_p = (2.67530^{+0.10})10^8 r \cdot s^{-1} T^{-1}$	NMR in known magnetic field
	$\pm 2.79283\ 10$	(65Co20)	$\gamma_p = (2.67525^{+0.10})10^8 r \cdot s^{-1} T^{-1}$	
	$\pm 2.79288\ 10$	(65Hu13)	$\gamma_p = (2.67523^{+0.10})10^8 r \cdot s^{-1} T^{-1}$	
	$\pm 2.79277^{+0.5}$	63Sa04	$\omega_p/\omega_{cyc} = 2.792676\ 50$	NMR ( $H_2O + MnSO_4$ ); decelerating cyclotron
	$\pm 2.79277\ 7$	(69TaPa)	$\omega_p/\omega_{cyc} = 2.79270^{+0.07}$	#Includes additional corrections
	$\pm 2.79280\ 2$	63Sa05	$\omega_e/\omega_p = 657.4621\ 25$	NMR (liquid paraffin); measured cyclotron frequency of free electrons
	$\pm 2.79281\ 15$	(69TaPa)	$\mu_p = (15.21043^{+0.6})10^{-4} \mu_B$ $\mu_p = (15.21046^{+0.84})10^{-4} \mu_B$	
	$\pm 2.79277\ 2$	63Vi04	$\gamma_p = (2.67513\ 1)10^8 r \cdot s^{-1} T^{-1}$	NMR in weak magnetic field ( $H_2O$ )
	$\pm 2.79276\ 2$	(65Co20)	$\gamma_p = (2.675188^{+0.8})10^8 r \cdot s^{-1} T^{-1}$	
	$\pm 2.79278\ 2$	(65Hu13)	$\gamma_p = (2.675132^{+0.8})10^8 r \cdot s^{-1} T^{-1}$	
	$\pm 2.79276\ 3$	(69TaPa)	$\gamma_p = (2.675144^{+0.16})10^8 r \cdot s^{-1} T^{-1}$	
	$\pm 2.79286\ 2$	65Ma25	$\mu_p = 2.79279\ 2$	cyclotron frequency of ${}^4He^+$ , ${}^{20}Ne^{2+}$ , ${}^{20}Ne^+$ ; NMR ( $H_2O + CuCl_2$ )
		(69TaPa)	$\mu_p = 2.792794^{+0.17}$	
	$+3.0\ 3$	66Be50	$\gamma_p = -(2.9\ 3)10^8 r \cdot s^{-1} T^{-1}$	NMR in weak rotating rf field ( $H_2O$ )
	$\pm 2.792782\ 17$	66My01 (69TaPa)	$g_J(H, {}^2S_{1/2})/g = 658.21049\ 20$ $\mu_p = (15.210326\ 4)10^{-4} \mu_B$ $g_J(H)/g = 658.21053^{+0.20}$	MASER See 70Wi22 below

Table A: Neutron, Proton, and Anti-Proton Moments — Continued

I	$\mu$	Refer.	Quantity Measured	Method (Compound)
	$\pm 2.79273$	66Ya07	$\gamma_p = (2.675071)10^8 \text{ r} \cdot \text{s}^{-1} \text{T}^{-1}$	NMR in strong field ( $\text{H}_2\text{O}$ )
	$\pm 2.79274^c$		$\gamma_p = (2.67510^c)10^8 \text{ r} \cdot \text{s}^{-1} \text{T}^{-1}$	
	$\pm 2.79277^d 4$	(69TaPa)	$\gamma_p = (2.675105^{16} 20)10^8 \text{ r} \cdot \text{s}^{-1} \text{T}^{-1}$	
	$\pm 2.79267^e 12$	67Ma17		Determined from existing time-of-flight and magnetic analysis data on $^{27}\text{Al}(\text{p},\gamma)^{28}\text{Si}$ resonance and $^7\text{Li}(\text{p},\text{n})^7\text{Be}$ threshold
	$\pm 2.79267^d 13$	(69TaPa)	$\mu_p = 2.79260^{df} 13$	
	$\pm 2.79281^f 5$	67Pe09	$\omega_p/\omega_{\text{cyc}} = 2.79274 5$	NMR ( $\text{H}_2\text{O}$ ); omegatron ( $\text{H}_2^+$ ; $\text{HD}^+$ ; $\text{D}_2^+$ )
	$\pm 2.792773$	68Dr06	$\gamma_p = (2.6751526)10^8 \text{ r} \cdot \text{s}^{-1} \text{T}^{-1}$	Free precession in the field of a standard solenoid ( $\text{H}_2\text{O}$ )
		(69TaPa)	$\gamma_p = (2.6751465^{16})10^8 \text{ r} \cdot \text{s}^{-1} \text{T}^{-1}$	[Fredericksburg, Va. 1958]
		(69TaPa)	$\gamma_p = (2.6751555^{16})10^8 \text{ r} \cdot \text{s}^{-1} \text{T}^{-1}$	[Washington, D.C., 1960–1967]
		(69TaPa)	$\gamma_p = (2.6751526^{16})10^8 \text{ r} \cdot \text{s}^{-1} \text{T}^{-1}$	[Gaithersburg, Md. 1968]
	$\pm 2.792773 30$	(69TaPa)	$\gamma_{p,\text{ave}} = (2.6751525^{16} 99)10^8 \text{ r} \cdot \text{s}^{-1} \text{T}^{-1}$	
	$\pm 2.79276^g 3$	68Ha49	$\gamma_p = (2.675138 11)10^8 \text{ r} \cdot \text{s}^{-1} \text{T}^{-1}$	Free precession in an air-core field-coil system ( $\text{H}_2\text{O}$ )
		(69TaPa)	$\gamma_p = (2.6751392^{16} 86)10^8 \text{ r} \cdot \text{s}^{-1} \text{T}^{-1}$	
	$\pm 2.792782 18$	68Kl02	$\omega_p/\omega_e = (15.2099441 11)10^{-4}$ $\omega_p/\omega_e = (15.210329 9)10^{-4}$	NMR ( $\text{H}_2\text{O} + 0.2\text{M CuSO}_4$ in cylinder); cyclotron resonance of electron
	$\pm 2.79278^h 3$	68St27	$\gamma_p = (2.675162 14)10^8 \text{ r} \cdot \text{s}^{-1} \text{T}^{-1}$	Free precession in field of Helmholtz coils ( $\text{H}_2\text{O}$ )
	$\pm 2.79275$	(69TaPa)	$\gamma_p = (2.6751349^{16})10^8 \text{ r} \cdot \text{s}^{-1} \text{T}^{-1}$	
		69Te08	$\gamma_p = (2.67512)10^8 \text{ r} \cdot \text{s}^{-1} \text{T}^{-1}$	Value adopted by BIPM for spherical sample of $\text{H}_2\text{O}$
	$\pm 2.792766 15$	70Wi22	$g_J(\text{H})/g_p(\text{H}) = 658.210705^j 6$	MASER (atomic H)
			<b>Anti-Proton</b>	
	$-1.8 12$	62Bu19		Double scattering

<sup>a</sup> Includes diamagnetic correction<sup>b</sup> Includes diamagnetic and paramagnetic corrections<sup>c</sup> Corrected for standard BIPM ampere<sup>d</sup> Includes corrections sent by experimenters to compilers 65Co20 or 69TaPa<sup>e</sup> Value corrected for solution concentration, shape of holder, and shielding of electrons and neighboring molecules<sup>f</sup> For spherical container of  $\text{H}_2\text{O}$ <sup>g</sup> In terms of NBS as-maintained Ampere<sup>h</sup> Includes corrections for better values of "g", the acceleration of gravity, and the diamagnetic correction<sup>i</sup> Calculated using  $\mu_e = 1.001159639\mu_B$ ,  $g_J = g_s(1 - 17.75 \text{ ppm})$ ,  $\sigma(\text{H}_2) = 26.6 3 \text{ ppm}$ ,  $\sigma(\text{H}_2\text{O}) = 26.0 3 \text{ ppm}$ , and  $\sigma(\text{oil}) = 29.7 6 \text{ ppm}$ <sup>j</sup> Calculated using  $g_J(\text{H})/g_p(\text{H}) = (g_s/g_p)(1 - 0.204 \text{ ppm})$ . See [69TaPa], page 324.

**Table B: Nuclear Moments  
by  
Paramagnetic Resonance**

**Introduction**

Paramagnetic resonance provides a means of studying the Zeeman levels of a paramagnetic system which may be ionic, atomic, or molecular. The sample can be in the form of a gas, crystal, or solution. To be paramagnetic the system must have one or more electrons which are magnetically unpaired.

When the sample is placed in an external magnetic field, the interaction of the electron with the field causes a splitting of the electronic states. The interaction of the electron with the nuclear magnetic moment causes each of these states to be split again into  $2I+1$  levels (see figure 1). In practice, the sample is placed in a resonant microwave cavity in the region where the microwave magnetic field is perpendicular to the external magnetic field. The microwave frequency  $\nu_0$  is maintained constant and equal to the natural frequency of the cavity while the external field is varied slowly. When the energy difference between two levels, for which a transition is allowed, satisfies the condition  $|E_2 - E_1| = h\nu_0$ , an absorption of microwave energy is observed.

The nuclear spin  $I$  is indicated by the multiplicity  $(2I+1)$  of the spectrum. The magnetic moment can be calculated from the spacing of the resonance lines if wavefunctions for the electrons for the appropriate atom or ion are available. The ratio of the magnetic moments of two isotopes can be determined simply from the relative splitting factors of the respective resonance patterns. If the nuclear magnetic moment of one isotope is known from a technique such as nuclear magnetic resonance, which gives a rather precise value of the magnetic moment, the moment of the second isotope can be determined from the ratio with greater accuracy than by direct calculation.

A variation of the paramagnetic resonance method for the determination of  $g_I$  is the Electron-Nuclear

Double Resonance (ENDOR) experiment described by Feher [56Fe43] and by Pipkin and Culvahouse [58Pi43]. In a strong field the ground-state energy level is split into states specified by  $m_J$  and  $m_I$ . Figure 2 represents a typical splitting for a case in which  $J=1/2$  and  $I=1$ . The transition labeled A,  $(m_J=+1/2, m_I=-1) \leftrightarrow (m_J=-1/2, m_I=-1)$ , can be induced to saturation with a strong microwave signal. The transition labeled B,  $(+1/2, 0) \leftrightarrow (+1/2, -1)$ , can be induced by an appropriate radio frequency signal, which then decreases the population of the  $(+1/2, -1)$  state and increases the microwave absorption. Similarly, the transition labeled C,  $(-1/2, -1) \leftrightarrow (-1/2, 0)$ , can be induced and detected. Since the difference between pairs of  $m_I$  transition frequencies such as these depends only upon the interaction of the nuclear moment with the external field, the nuclear  $g_I$ -value can be calculated directly.

The interaction of the nuclear quadrupole moment with an inhomogeneous electric field at the nucleus causes second-order shifts in the levels, from which the quadrupole coupling constant can be determined. The evaluation of the quadrupole moment from the coupling constant depends upon a calculation of the field inhomogeneity at the nucleus, which may be uncertain by a few percent. In addition, the nuclear electric quadrupole moment causes a polarization of the atomic core electrons (Sternheimer effect) which can affect the evaluation of the field gradient by tens of percent.

A very thorough discussion of the method and theory can be found in a recent book by Abragam and Bleaney [70Ab20]. Earlier helpful reviews include those by Low [60Lo05] and Bowers and Owen [55Bo56]. Data on observed  $g_I$  or splitting factors have been omitted intentionally since these are characteristic of the lattice as well as the nucleus in question. Paramagnetic resonance data on crystals are given by Bowers and Owen [55Bo56], Orton [59Or36] and Konig [66Ko25].

The last systematic literature search for information included in the table was in early 1971.

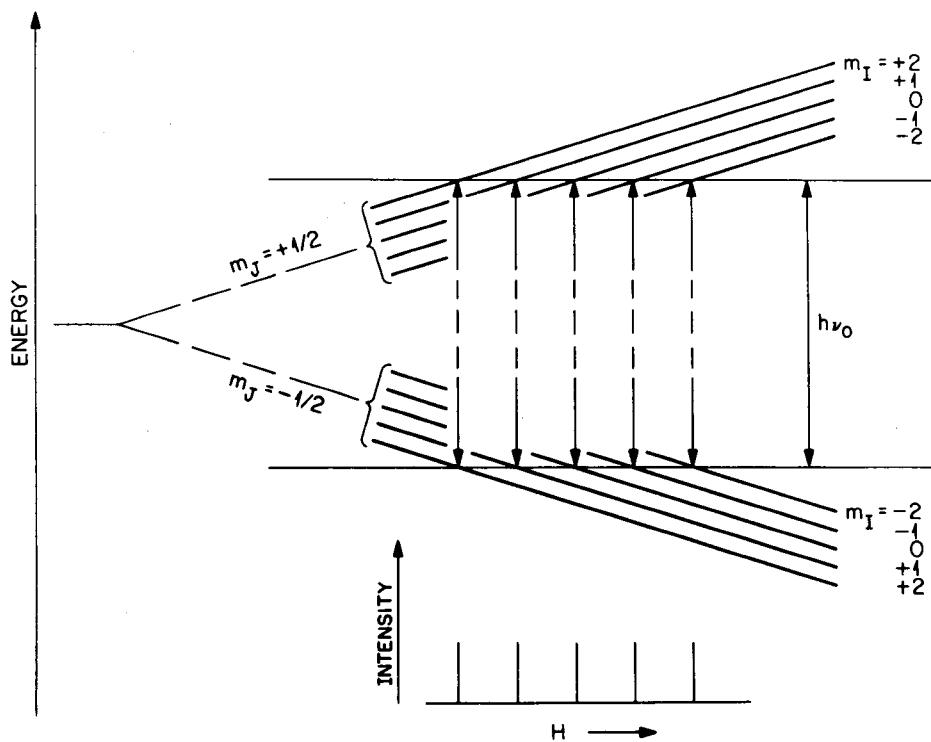


FIGURE 1. Schematic Zeeman energy level diagram for a state with  $J=1/2$ ,  $I=2$ . The applied magnetic field  $H$  increases to the right. The spectrum for the hyperfine components of an  $m_J=+1/2 \leftrightarrow -1/2$  transition is shown below.

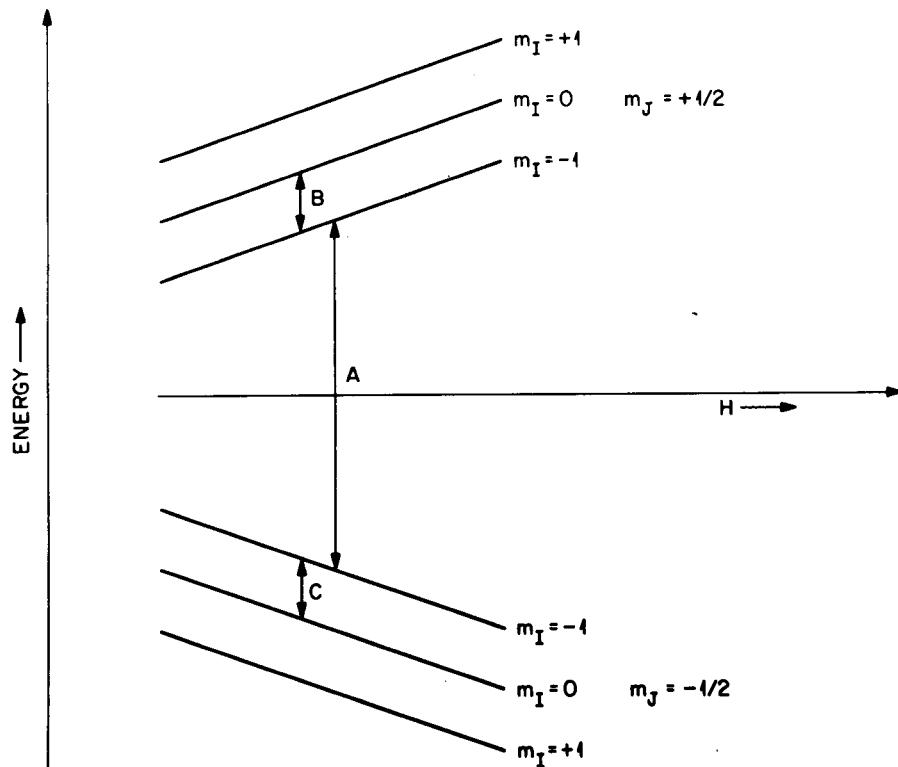


FIGURE 2. Schematic diagram of the energy levels and transitions involved in a typical ENDOR experiment. Transition A ( $\Delta m_J = \pm 1$ ) is saturated by an intense microwave signal. The application of an rf field makes possible the observation of transitions B and C ( $\Delta m_I = \pm 1$ ), from which  $g_I$  may be determined.

## Explanation of Table B

Nucleus	Chemical symbol with $Z$ - and $A$ -numbers
$T_{1/2}$	Half-life of radioactive nucleus
$I$	Nuclear spin, in units of $h/2\pi$
$\mu$	Nuclear magnetic dipole moment, in nuclear magnetons, given with diamagnetic correction. See Policies, Diamagnetic corrections, for factors used
$Q$	Nuclear electric quadrupole moment, in barns, as given by the experimenter Values marked by an asterisk, *, indicate that the experimenter has made some polarization or Sternheimer correction in computing the moment.
Refer.	Reference key
$\mu^1/\mu^2$	Ratio of the magnetic moments of the indicated pair of nuclei as determined by the relative spread of the resonance pattern or by the ratio of the magnetic interaction constants Values marked with an 'e' are determined from the $g$ -values.
Valence and Lattice	The valence of the paramagnetic ion and the chemical formula of the crystal used For diluted crystals, the chemical symbol of the element which is replaced by the element under study is italicized. The number of waters of crystallization is represented by the italicized number following the dot. Example: $ZnK_2(SO_4)_2 \cdot 6$ for $^{56}\text{Co}$ indicates that a small fraction of the Zn atoms are replaced by $^{56}\text{Co}$ atoms.

Table B: Nuclear Moments by Paramagnetic Resonance

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	$\mu^1/\mu^2$	Valence and Lattice
$^1H$					56W46	$\Delta\nu(^2S_{1/2})=1420.40580\ 6$ MHz	
$^{14}N$				$\pm 0.014^e$	65Ev09		N impurity in diamond
$^{14}N$				$+0.057$ to $0.011^\ddagger$	65Lo12		N impurity in diamond
						$\dagger$ Depends upon choice of $q$ , the field gradient at the nucleus	
$^{17}O$				-0.026* 3	57K27		Atomic O
$^{17}O$				-0.0205 <sup>e</sup>	62Ko22		$^3P_2$ state
$^{17}O$				-0.0256* <sup>e</sup> 5	68Sc18 (65Ha35)	$a=-219.61\ 5MHz$ $b=-10.438\ 30MHz$ $a=4.738\ 36MHz$ $b=5.199\ 90MHz$	$^3P_1$ state atomic $^{17}O$ gas atomic $^{17}O$ gas
$^{17}O$				-0.025* <sup>e</sup> 3	69Go12 (65Ha35)		atomic $^{17}O$ gas
$^{17}O$				-0.0263* <sup>e</sup>	69Ke07 (65Ha35)		
$^{17}O$				-0.02578* <sup>e</sup>	69Sc34 (65Ha35)		
$^{19}F$					61Ra14	$\Delta\nu(^2P_{3/2})=4020.01\ 2MHz$	
$^{25}Mg$		5/2			57W13		MgO, irradiated
$^{31}P$		1/2			54F41		P doped Si
$^{31}P$			$\pm 1.133^E\ I$		69Se11		$(PO_4)^{2-}$ or $(PO_3)^{2-}$ natural CaCO <sub>3</sub> crystal
$^{32}P$	14d	1	-0.2523 <sup>E</sup> 3		57F32		$^{32}P$ in Si plates
$^{33}S$		3/2 <sup>E</sup>			65Lu06		1+ S doped Si
$^{47}Ti$		5/2			61Ga16		$^{47}Ti_2(SO_4)_3$
$^{47}Ti$		5/2			62Mc05		3+ Al acetylacetone
$^{47}Ti$		5/2			62Wa03		3+ TiCl <sub>3</sub>
$^{47}Ti$					68Lo05	$^{47}/^{49}=1.400\ I$	3+ CaF <sub>2</sub>
$^{49}Ti$		7/2			61Ga16		$^{49}Ti_2(SO_4)_3$
$^{49}Ti$		7/2			62Mc05		3+ Al acetylacetone
$^{49}Ti$		7/2			62Wa03		3+ TiCl <sub>3</sub>
$^{49}V$	330d	7/2 <sup>P</sup>	$\pm 4.5^P$		57W17		4+ V-cupferron chelate
$^{50}V$	>40Jy	6	$\pm 3.34\ I$		52B63	$^{50}/^{51}=0.651\ 2$	2+ K <sub>4</sub> Fe(CN) <sub>6</sub> <sup>•</sup> 3
$^{50}V$	>40Jy	6	$\pm 3.346\ 8$		53K41	$^{50}/^{51}=0.6501\ 14$	2+ Zn(NH <sub>4</sub> ) <sub>2</sub> (SO <sub>4</sub> ) <sub>2</sub> <sup>•</sup> 6
$^{51}V$		7/2			51B43		2+ Zn(NH <sub>4</sub> ) <sub>2</sub> (SO <sub>4</sub> ) <sub>2</sub> <sup>•</sup> 6
$^{51}V$		7/2			52B63		2+ K <sub>4</sub> Fe(CN) <sub>6</sub> <sup>•</sup> 3
$^{53}Cr$		3/2	$\pm 0.58$		52B66		3+ K <sub>3</sub> Co(CN) <sub>6</sub>
$^{53}Cr$			$\pm 0.475$		57L50		3+ MgO
$^{53}Cr$				$-0.03^E\dagger$	61Te01		3+ Al <sub>2</sub> O <sub>3</sub>
						$\dagger$ Magnitude and even sign may be wrong, from comparison of hyperfine fields and electric field gradients for impurities in corundum [63La16]	
$^{53}Cr$				$<+0.05^E$	64Ar23		3+ Al <sub>2</sub> O <sub>3</sub>
$^{53}Cr$				$\sim 0.024^e$			
$^{53}Cr$			$-0.4735^E\dagger\ 4$		67Wo04		3+ MgO at 4.2°K
						$\dagger$ Includes estimated paramagnetic correction	

Table B: Nuclear Moments by Paramagnetic Resonance — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	$\mu^1/\mu^2$	Valence and Lattice
$^{52}_{25}\text{Mn}$	5.7d	6	$\pm 2.97$ 15		61Je04	$^{52}_{55}=0.86$ 4	2+ $\text{La}_2\text{Mg}_3(\text{NO}_3)_{12} \cdot 24$
$^{53}_{25}\text{Mn}$	2My	7/2	$\pm 5.018$ 7		56D45	$^{53}_{55}=1.455$ 2	2+ powdered $\text{SrCl}_2$
$^{54}_{25}\text{Mn}$	290d	3	$\pm 3.28$ 6		61Je04	$^{54}_{55}=0.952$ 18	2+ $\text{La}_2\text{Mg}_3(\text{NO}_3)_{12} \cdot 24$
$^{55}_{25}\text{Mn}$		5/2	$\pm 3.469^E$ 6	$\pm 0.20$ 4	51B30 60Lu02 60Sc17		2+ $\text{ZnSiF}_6 \cdot 6$ 1- Mn in Si 3+ $\text{K}_2\text{CrO}_4$ crystal
$^{55}_{25}\text{Mn}$			$\pm 3.4$		65Ik01		2+ Mn doped $\text{BaTiO}_3$
$^{55}_{25}\text{Mn}$			$+3.4486$ 15		67Dy02		2+ $\text{MgO}$ at 4.2°K
$^{55}_{25}\text{Mn}$			$+3.444^E$ 6		67Es04		2+ $\text{MgO}$
$^{55}_{25}\text{Mn}$			$\pm 3.4502^E$ 23		67Mi04	$\gamma/2\pi=10.500$ 7 kHz/gauss	2+ $\text{CaWO}_4$ , $\text{CaO}$ , $\text{ZnS}$
$^{57}_{26}\text{Fe}$		1/2			57G16		3+ $\text{FeCl}_3$ and Borax
$^{57}_{26}\text{Fe}$		1/2			58L64		Fe doped Si
$^{57}_{26}\text{Fe}$			$+0.0905^E$ 7		60Lu02		0 Fe doped Si
$^{57}_{26}\text{Fe}$			$+0.09042^E$ 7		65Lo11		3+ $\text{Fe}_2\text{O}_3$ diffused in $\text{MgO}$
$^{57}_{26}\text{Fe}$			$\pm 0.09054^E$ 15		70Ca15		3+ natural Fe impurity in $\text{CaO}$
$^{56}_{27}\text{Co}$	77d	4	$\pm 3.822$ 15		56B69	$^{56}_{59}=0.828$ 3	2+ $\text{ZnK}_2(\text{SO}_4)_2 \cdot 6$
$^{56}_{27}\text{Co}$	77d	4	$\pm 3.831$ 12		56J06	$^{59}_{56}=1.205$ 2	2+ $\text{ZnK}_2(\text{SO}_4)_2 \cdot 6$
$^{57}_{27}\text{Co}$	270d	7/2	$\pm 4.62$ 4		56B69	$^{57}_{59}=1.00$ 1	2+ $\text{ZnK}_2(\text{SO}_4)_2 \cdot 6$
$^{58}_{27}\text{Co}$	71d	1,2?	$\pm 4.032$ 14		57D38	$^{58}_{59}=0.8734$ 24 $^{58}_{60}=1.0645$ 20	2+ $\text{ZnK}_2(\text{SO}_4)_2 \cdot 6$
$^{59}_{27}\text{Co}$		7/2			51B38		2+ $\text{Zn}(\text{NH}_4)_2(\text{SO}_4)_2 \cdot 6$
$^{60}_{27}\text{Co}$	5.3y	5	$\pm 3.781$ 11		56D08	$^{60}_{59}=0.8191$ 16	2+ $\text{Zn}(\text{NH}_4)_2(\text{SO}_4)_2 \cdot 6$
$^{60}_{27}\text{Co}$	5.3y		$\pm 3.787$ 18		57D38	$^{58}_{60}=1.0645$ 20	2+ $\text{ZnK}_2(\text{SO}_4)_2 \cdot 6$
$^{61}_{28}\text{Ni}$		3/2			58W52		Ni, As doped Ge
$^{61}_{28}\text{Ni}$			$\pm 0.9^c$		62Be15		2+ Ni doped Ge
$^{61}_{28}\text{Ni}$			$\pm 0.748^E$ 7		63Lo05		Ni doped $\text{MgO}$
							2+ $\text{Al}_2\text{O}_3$
$^{63}_{29}\text{Cu}$				$\pm 0.11$	51A28		2+ Tutton salts
$^{63}_{29}\text{Cu}$				$-0.16$ 3	55B21		2+ $\text{La}_2\text{Mg}_3(\text{NO}_3)_{12} \cdot 24$
$^{63}_{29}\text{Cu}$					63Bl27	$A^{63}/A^{65}=0.933559^E$ 7	3+ $\text{Al}_2\text{O}_3$
$^{63}_{29}\text{Cu}$					68Ma22	$^{63}_{65}=0.9328$ 8	2+ $\text{Mg}(\text{C}_2\text{H}_3\text{O}_2)_2$
$^{63}_{29}\text{Cu}$				$-0.15$ 2	69Ri07		2+ $\text{ZnWO}_4$
$^{65}_{29}\text{Cu}$				$\pm 0.11$	51A28		2+ Tutton salts
$^{65}_{29}\text{Cu}$				$-0.15$ 3	55B21		2+ $\text{La}_2\text{Mg}_3(\text{NO}_3)_{12} \cdot 24$
$^{65}_{25}\text{Cu}$				$0.14$ 2	67Ga03 69Ri07	$^{65}_{63}=1.063$ 2	2+ doped $\text{ZnWO}_4$ crystal
$^{75}_{33}\text{As}$		3/2			54F41		2+ $\text{ZnWO}_4$
$^{76}_{33}\text{As}$	26.5h	2(1?)	$-0.903$ 5		58P43	$^{76}_{75}=-0.6293$ 4	As doped Si As doped Si
$^{87}_{38}\text{Sr}$		9/2		$+0.154$	65Cu05		n irradiated $\text{SrO}$ crystal
$^{93}_{41}\text{Nb}$			$\pm 6.17$ 16		69Ki19		4+ $\text{CaWO}_4$
$^{95}_{42}\text{Mo}$		5/2			56O04		5+ $\text{K}_3(\text{InCl}_6) \cdot 2$
$^{97}_{42}\text{Mo}$		5/2			56O04		5+ $\text{K}_3(\text{InCl}_6) \cdot 2$
$^{99}_{43}\text{Tc}$	210ky	9/2			58L62		4+ $\text{K}_2\text{PtCl}_6$ crystal
$^{99}_{44}\text{Ru}$		5/2			52G19	$^{101}_{99}=1.09$ 3	3+ $\text{Co}(\text{NH}_3)_6\text{Cl}_3$
$^{99}_{44}\text{Ru}$					68Ya06	$^{101}_{99}=1.12$	3+ $\text{TiO}_2(4.2^\circ\text{K})$
$^{101}_{44}\text{Ru}$		5/2			52G19		3+ $\text{Co}(\text{NH}_3)_6\text{Cl}_3$

Table B: Nuclear Moments by Paramagnetic Resonance — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	$\mu^1/\mu^2$	Valence and Lattice
$^{110m}_{47}\text{Ag}$	253d	6	$\pm 3.55 \pm 4$		66Ea01		2+ $[(\text{iso}-\text{C}_3\text{H}_7)_2\text{NCS}_2]\text{Ag}$ ‡Includes $\Delta(\text{hfs anomaly})$ correction=(3.7 10)%
$^{119}_{50}\text{Sn}$					67Su06	$^{119}_{117}=1.046\ 2$	3+ Sn doped ZnS
$^{121}_{51}\text{Sb}$			$\pm 3.3600^{\text{E}} 17$		58E03	$^{121}_{123}=1.31437\ 6$	Sb doped Si
$^{122}_{51}\text{Sb}$	2.8d	2	$-1.904^{\text{E}} 20$		58P45	$^{122}_{121}=-0.5678\ 4$	Sb doped Si
$^{123}_{51}\text{Sb}$			$\pm 2.5484^{\text{E}} 10$		58E03		Sb doped Si
$^{141}_{58}\text{Ce}$	33d	7/2	$\pm 0.89\ 9$		57K13		
$^{141}_{58}\text{Ce}$	33d		$\pm 1.18^{\text{E}} 12$		62Li06		
$^{141}_{58}\text{Ce}$	33d		$\pm 0.968^{\text{E}} 30$		63Bl25		
$^{141}_{59}\text{Pr}$		5/2			51D28		3+ $\text{PrCl}_3$ • 7
$^{141}_{59}\text{Pr}$		5/2	$\pm 3.94\ 20$		58B35		3+ $\text{Y}(\text{C}_2\text{H}_5\text{SO}_4)_3$ • 9
$^{141}_{59}\text{Pr}$		5/2	$\pm 4.6$		58Hu17		3+ $\text{LaCl}_3$
$^{141}_{59}\text{Pr}$			$\pm 4.0^{\text{E}}$		62Fr14		
$^{141}_{59}\text{Pr}$			$\pm 5.1^{\text{E}} 3$		62Li06		
$^{141}_{59}\text{Pr}$					(58B35)		
$^{141}_{59}\text{Pr}$			$\pm 4.24^{\text{E}} 10$		63Bl25		
$^{143}_{60}\text{Nd}$	7/2		$\pm 1.04$	$\pm <1$	55Bl51	$^{143}_{145}=\pm 1.6083\ 12$	3+ $\text{La}(\text{C}_2\text{H}_5\text{SO}_4)_3$ • 9
$^{143}_{60}\text{Nd}$	7/2				57K13	$^{143}_{145}=\pm 1.614\ 2$	3+ $\text{La}_2\text{Mg}_3(\text{NO}_3)_{12}$ • 24
$^{143}_{60}\text{Nd}$	7/2		$\pm 1.1$		58Hu17		3+ $\text{LaCl}_3$
$^{143}_{60}\text{Nd}$			$\pm 0.99^{\text{E}}$		62Fr14		
$^{143}_{60}\text{Nd}$			$-1.086^{\text{E}} 60$	+0.0206 30	62Ha29		3+ $\text{LaCl}$
$^{143}_{60}\text{Nd}$			$\pm 1.24^{\text{E}} 20$		62Li06		
$^{143}_{60}\text{Nd}$					(55Bl51)		
$^{143}_{60}\text{Nd}$			$\pm 1.10\ 10$		66Er08	$^{143}_{145}=1.60892\ 10$ $=1.60886\ 29$ $Q^{143}/Q^{145}=-\pm 1.45\ 65$	3+ $\text{LaCl}_3$ at 14.4°K; $H_o=0$ 3+ $\text{La}(\text{C}_2\text{H}_5\text{SO}_4)_3$ • 9 at 4°K; $H_o=0$
						‡Some confusion of signs in paper	
$^{145}_{60}\text{Nd}$	7/2		$\pm 0.64$	$\pm <1$	55Bl51		3+ $\text{La}(\text{C}_2\text{H}_5\text{SO}_4)_3$ • 9
$^{145}_{60}\text{Nd}$	7/2		$\pm 0.7$		58Hu17		3+ $\text{LaCl}_3$
$^{145}_{60}\text{Nd}$			$+0.675^{\text{E}} 40$	+0.0105 20	62Ha29	$^{143}_{145}=+1.60883\ 4$ $Q^{143}/Q^{145}=+1.96\ 2$	3+ $\text{LaCl}$
$^{145}_{60}\text{Nd}$			$\pm 0.77^{\text{E}} 20$		62Li06		
$^{145}_{60}\text{Nd}$					(55Bl51)		
$^{145}_{60}\text{Nd}$			$\pm 0.68\ 7$		66Er08		
$^{147}_{60}\text{Nd}$	11d	5/2	$\pm 0.56\ 6$		57K13	$^{143}_{147}=\pm 1.844\ 2$ ( $^{143}_{147}=1.844\ 2$ )	3+ $\text{LaCl}_3; H_o=0$ 3+ $\text{La}(\text{C}_2\text{H}_5\text{SO}_4)_3$ • 9; $H_o=0$
$^{147}_{60}\text{Nd}$	11d		$\pm 0.589\ 30$		62Ha29		3+ $\text{La}_2\text{Mg}_3(\text{NO}_3)_{12}$ • 24
$^{147}_{60}\text{Nd}$	11d		$\pm 0.67^{\text{E}} 7$		62Li06		
$^{147}_{61}\text{Pm}$	2.6y	7/2	$\pm 3.0\ 3$		61St18		3+ $\text{La}(\text{C}_2\text{H}_5\text{SO}_4)_3$ • 9
$^{147}_{61}\text{Pm}$	2.6y		$\pm 2.55^{\text{E}} 6$		63Bl25		
$^{147}_{62}\text{Sm}$		7/2			52B21	$^{147}_{149}=\pm 1.222\ 8$	3+ $\text{La}(\text{C}_2\text{H}_5\text{SO}_4)_3$ • 9
$^{147}_{62}\text{Sm}$			$\pm 0.83\ 15$	$\pm <0.7$	55Bl51		3+ $\text{La}(\text{C}_2\text{H}_5\text{SO}_4)_3$ • 9
$^{147}_{62}\text{Sm}$		7/2	$\pm 0.86$		58Hu17		3+ $\text{LaCl}_3$
$^{147}_{62}\text{Sm}$			$\pm 0.85^{\text{E}}$		62Fr14		
$^{147}_{62}\text{Sm}$			$\pm 1.04^{\text{E}} 18$		62Li06		
$^{147}_{62}\text{Sm}$					(55Bl51)		
$^{147}_{62}\text{Sm}$			$\pm 0.812^{\text{E}} 22$		63Bl25		
$^{149}_{62}\text{Sm}$		7/2			52B21		3+ $\text{La}(\text{C}_2\text{H}_5\text{SO}_4)_3$ • 9
$^{149}_{62}\text{Sm}$			$\pm 0.68\ 10$	$\pm <0.7$	55Bl51		3+ $\text{La}(\text{C}_2\text{H}_5\text{SO}_4)_3$ • 9
$^{149}_{62}\text{Sm}$		7/2	$\pm 0.75$		58Hu17		3+ $\text{LaCl}_3$

Table B: Nuclear Moments by Paramagnetic Resonance — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	$\mu^1/\mu^2$	Valence and Lattice
$^{149}_{62}\text{Sm}$			$\pm 0.85^\circ 15$		62Li06 (55Bl51)		
$^{149}_{62}\text{Sm}$			$\pm 0.656^\circ 18$		63Bl25		
$^{151}_{63}\text{Eu}$		5/2			55B16	$^{151}_{153} = \pm 2.24 3$	2+ SrS phosphor
$^{151}_{63}\text{Eu}$		5/2			57A05	$^{151}_{153} = \pm 2.264 6$	2+ KCl powder
$^{151}_{63}\text{Eu}$		5/2	$+3.465^\circ 2$		57M19	$^{151}_{153} = +2.24$	2+ SrSeu
$^{151}_{63}\text{Eu}$		5/2	$+3.465^\circ 2$		62Ba12	$^{151}_{153} = 2.2632^\circ 26$	2+ $\text{CaF}_2$
$^{151}_{63}\text{Eu}$					69Ab12	$^{151}_{153} = 2.25313 15$	
$^{151}_{63}\text{Eu}$						$^{151}_{153} = 2.263 14$	2+ $\text{ThO}_2$ at $< 77^\circ\text{K}$
$^{151}_{63}\text{Eu}$					70Ki13	$Q^{151}/Q^{153} = 0.391 8$	2+ $\text{CaWO}_4$
$^{151}_{63}\text{Eu}$						$^{151}_{153} = 2.266^\circ 5$	
$^{151}_{63}\text{Eu}$						$A^{151}/A^{153} = 2.2533 3$	
$^{151}_{63}\text{Eu}$						$Q^{151}/Q^{153} = 0.39198 12$	
$^{152}_{63}\text{Eu}$	13y	3	$\pm 1.93 2$		57A05	$^{152}_{151} = \pm 0.5574 60$	2+ KCl powder
$^{152}_{63}\text{Eu}$	13y	3	$\pm 1.96 2$		57M19	$^{151}_{152} = \pm 1.77 2$	2+ SrS•Eu
$^{153}_{63}\text{Eu}$		5/2	$\pm 1.55 2$		55B16	$^{151}_{153} = 2.24 3$	2+ SrS phosphor
$^{153}_{63}\text{Eu}$			$+1.531^\circ 2$		62Ba12		2+ $\text{CaF}_2$
$^{153}_{63}\text{Eu}$			$+1.531^\circ 3$		70Ki13	#Spherical average; $g_1$ anisotropic.	
$^{154}_{63}\text{Eu}$	16y	3	$\pm 2.000 6$		57A05	$^{154}_{153} = \pm 1.308 4$	2+ KCl powder
$^{155}_{64}\text{Gd}$		3/2	$\pm 0.23 2$		56L29	$^{155}_{157} = \pm 0.75 7$	3+ $\text{Bi}_2\text{Mg}_3(\text{NO}_3)_{12} \cdot 24$
$^{155}_{64}\text{Gd}$		3/2	$\pm 0.240 4$		57M55	$^{155}_{157} = \pm 0.736 12$	3+ SrS• $^{155}\text{Gd}$
$^{155}_{64}\text{Gd}$					59L63	$^{155}_{157} = \pm 0.7495 45$	3+ $\text{ThO}_2\text{-Gd}$
$^{155}_{64}\text{Gd}$					60He17	$^{155}_{157} = \pm 0.763 6$	3+ $\text{CaWO}_4$
$^{155}_{64}\text{Gd}$			$\pm 0.28^\circ 4$		63Bl25		
$^{155}_{64}\text{Gd}$			$-0.254 3$		65Hu14	$(^{155}_{157} = 0.7495 45)$	3+ $\text{ThO}_2$
$^{155}_{64}\text{Gd}$					67Ma56	$^{155}_{157} = 0.7628 8$	3+ $\text{ThO}_2$ crystal
$^{155}_{64}\text{Gd}$					68Ma48	$^{155}_{157} = 0.7624 10$	3+ $\text{CaCO}_3$
$^{155}_{64}\text{Gd}$			$-0.2585^\circ 6$		69Ba15	$^{155}_{157} = 0.7633^\circ 45$	3+ $\text{CeO}_2$ crystal
$^{155}_{64}\text{Gd}$						$A^{155}/A^{157} = 0.7621 5$	
$^{155}_{64}\text{Gd}$		3/2	$\pm 0.306^\circ$		70Ra42	$Q^{155}/Q^{157} = 0.94 1$	3+ $\text{YPO}_4$ crystal
$^{157}_{64}\text{Gd}$		3/2	$\pm 0.306^\circ$		56L29	$^{151}\text{Eu}/^{157}\text{Gd} = \pm 11.3$	3+ $\text{Bi}_2\text{Mg}_3(\text{NO}_3)_{12} \cdot 24$
$^{157}_{64}\text{Gd}$		3/2	$\pm 0.327^\circ 1$		57M55	#Used $\mu(^{151}\text{Eu})_{\text{uncorrected}} = 3.440 1$	
$^{157}_{64}\text{Gd}$		3/2	$\pm 0.327^\circ 1$			$^{151}\text{Eu}/^{157}\text{Gd} = \pm 10.60 3$	3+ SrS• $^{157}\text{Gd}$
$^{157}_{64}\text{Gd}$						#Used $\mu(^{151}\text{Eu})_{\text{uncorrected}} = 3.440 1$	
$^{157}_{64}\text{Gd}$			$\pm 0.38^\circ 5$		63Bl25		
$^{157}_{64}\text{Gd}$			$-0.339^\circ 3$		65Hu14		3+ $\text{ThO}_2$ crystal
$^{157}_{64}\text{Gd}$			$-0.3381^\circ 6$		69Ba15		3+ $\text{CeO}_2$ crystal
$^{157}_{64}\text{Gd}$			$-0.3395^\circ 6$				3+ $\text{ThO}_2$
$^{157}_{65}\text{Tb}$	>30y	[3/2]	$\pm 2.0 1$		68Ea04		
$^{158}_{65}\text{Tb}$	150y	3	$\pm 1.753 7$	+2.7 5	68Ea04		3+ $\text{Y}(\text{C}_2\text{H}_5\text{SO}_4)_3 \cdot 9$
$^{159}_{65}\text{Tb}$		3/2	$\pm 1.52 8$		58B35		3+ $\text{Y}(\text{C}_2\text{H}_5\text{SO}_4)_3 \cdot 9$
$^{159}_{65}\text{Tb}$		3/2	$\pm 1.5$		58Hu17		3+ $\text{Y}(\text{C}_2\text{H}_5\text{SO}_4)_3 \cdot 9$
$^{159}_{65}\text{Tb}$			$\pm 1.90^\circ$		62Li06		3+ $\text{LaCl}_3$
$^{159}_{65}\text{Tb}$					(58B35)		
$^{159}_{65}\text{Tb}$			$\pm 1.90^\circ 5$		63Bl25		
$^{159}_{65}\text{Tb}$			$\pm 1.6 2$		63Lo07	Used $\langle r^{-3} \rangle$ of Lindgren	3+ $\text{CaF}_2$
$^{159}_{65}\text{Tb}$			$+2.008^\circ 4$		65Ba49		4+ $\text{ThO}_2$
$^{160}_{65}\text{Tb}$	72d		$\pm 1.697 8$	+3.0 5	68Ea04		3+ $\text{Y}(\text{C}_2\text{H}_5\text{SO}_4)_3 \cdot 9$

Table B: Nuclear Moments by Paramagnetic Resonance — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	$\mu^1/\mu^2$	Valence and Lattice
$^{161}_{66}\text{Dy}$		5/2	-?0.37 4	+?1.1 4	58P11	$^{163}_{161} = -1.39\ 2$ $Q^{163}/Q^{161} = +1.18\ 15$	3+ $\text{La}_2\text{Mg}_3(\text{NO}_3)_{12} \cdot 24$
$^{161}_{66}\text{Dy}$			$\pm 0.46^\circ\ 5$		62Li06		
$^{161}_{66}\text{Dy}$			$\pm 0.455^\circ\ 10$	+1.35 <sup>c</sup> 30	63Bl25		
$^{161}_{66}\text{Dy}$			-?0.46 <sup>c</sup> 4		65Of03		3+ $\text{La}_2\text{Mg}_3(\text{NO}_3)_{12} \cdot 24$
$^{161}_{66}\text{Dy}$			-0.472 <sup>c</sup> 12		68Mu01		
$^{163}_{66}\text{Dy}$		5/2	+?0.51 6	+?1.3 4	58P11		3+ $\text{La}_2\text{Mg}_2(\text{NO}_3)_{12} \cdot 24$
$^{163}_{66}\text{Dy}$			$\pm 0.65^\circ\ 8$		62Li06		
$^{163}_{66}\text{Dy}$			+0.635 <sup>c</sup> 14	+1.62 <sup>c</sup> 40	63Bl25		
$^{165}_{67}\text{Ho}$		7/2	+3.31 17	+0.7 7	58B35		3+ $\text{Y}(\text{C}_2\text{H}_5\text{SO}_4)_3 \cdot 9$
$^{165}_{67}\text{Ho}$		7/2	$\pm 3.4$		58Hu17		3+ $\text{LaCl}_3$
$^{165}_{67}\text{Ho}$			$\pm 3.5^\circ$		62Fr14		
$^{165}_{67}\text{Ho}$			$\pm 4.1^\circ$		62Li06		
$^{165}_{67}\text{Ho}$					(58B35)		
$^{165}_{67}\text{Ho}$			+4.03 <sup>c</sup> 15		63Bl25		
$^{167}_{68}\text{Er}$		7/2			51B09		3+ $\text{La}(\text{C}_2\text{H}_5\text{SO}_4)_3 \cdot 9$
$^{167}_{68}\text{Er}$			$\pm 0.48$	$\pm 9.4$	55Bl51		3+ $\text{La}(\text{C}_2\text{H}_5\text{SO}_4)_3 \cdot 9$
$^{167}_{68}\text{Er}$		7/2	$\pm 0.11$		58Hu17		3+ $\text{LaCl}_3$
$^{167}_{68}\text{Er}$				$\pm 4^\circ$	58Mu08		
$^{167}_{68}\text{Er}$			$\pm 0.50^\circ$		62Fr14		
$^{167}_{68}\text{Er}$			$\pm 0.58^\circ$		62Li06		
$^{167}_{68}\text{Er}$					(55Bl51)		
$^{167}_{68}\text{Er}$			$\pm 0.563^\circ\ 6$		63Bl25		
$^{167}_{68}\text{Er}$			$\pm 0.56\ 5$		63Ra24		3+ $\text{CaF}_2$ crystal
$^{167}_{68}\text{Er}$			$\pm 0.56$		65Ab01		3+ $\text{Er}_2\text{O}_3$ doped $\text{ThO}_2$ crystal
$^{167}_{68}\text{Er}$				+3.0 4	66Be25	$\mu/Q < 0$	3+ $\text{MgO}$
$^{169}_{69}\text{Tm}$		1/2	$\pm 0.24\ 1$		61Ha37		3+ $\text{Tm}$ doped $\text{CaF}_2$
$^{169}_{69}\text{Tm}$		1/2	$\pm 0.23\ 2$		63Lo07	Used $\langle r^{-3} \rangle$ of Lindgren	2+ $\text{CaF}_2$
$^{169}_{69}\text{Tm}$			$\pm 0.236^\ddagger \text{E} 3$		65Be34		2+ $\text{CaF}_2$
							$\ddagger g$ , corrected for admixture of $\Gamma_8$ -excited state to $\Gamma_7$ -ground state
$^{171}_{70}\text{Yb}$		1/2	$\pm 0.43\ 5$		56C21	$^{173}_{171} = \pm 1.39\ 1$	3+ $\text{Y}(\text{CH}_3\text{COO})_3 \cdot 4$
$^{171}_{70}\text{Yb}$		1/2	$\pm 0.41\ 5$		60Lo01	$^{173}_{171} = 1.3749\ 50$	3+ $\text{CaF}_2$ ; site I
$^{171}_{70}\text{Yb}$			$\pm 0.52^\circ\ 6$		62Li06		
$^{171}_{70}\text{Yb}$					(56C21)		
$^{171}_{70}\text{Yb}$			$\pm 0.52\ 5$		63Lo07, 62Lo08	Used $\langle r^{-3} \rangle$ of Lindgren	3+ $\text{CaF}_2$ ; site II
$^{171}_{70}\text{Yb}$			$\pm 0.50$		65Ab01		3+ $\text{Yb}$ doped $\text{ThO}_2$
$^{171}_{70}\text{Yb}$					69Ba10	$A^{171}/A^{173} = -3.6302^\text{E} 4$	3+ $\text{CaF}_2$
$^{173}_{70}\text{Yb}$		5/2	$\pm 0.60\ 5$		56C21		3+ $\text{Y}(\text{CH}_3\text{COO})_3 \cdot 4$
$^{173}_{70}\text{Yb}$		5/2	$\pm 0.57\ 5$		60Lo01		3+ $\text{CaF}_2$ ; site I
$^{173}_{70}\text{Yb}$			$\pm 0.63^\circ$		62Fr14		
$^{173}_{70}\text{Yb}$			$\pm 0.72^\circ\ 7$		62Li6		
$^{173}_{70}\text{Yb}$					(56C21)		
$^{173}_{70}\text{Yb}$			$\pm 0.70\ 5$	$\pm 2.6\ 2$	63Lo07, 62Lo08	$^{173}_{171} = 1.362$ Used $\langle r^{-3} \rangle$ of Lindgren	3+ $\text{CaF}_2$ ; site II
$^{173}_{70}\text{Yb}$			$\pm 0.68$		65Ab01	$^{173}_{171} = 1.378\ 3$	3+ $\text{Yb}$ doped $\text{ThO}_2$
$^{173}_{70}\text{Yb}$					66Ti04	$^{173}_{171} = 1.383\ 8$	3+ $(\text{Yb}+\text{P})$ doped $\text{ZnTe}$
$^{173}_{70}\text{Yb}$					68Re06	$^{173}_{171} = 1.378\ 2$	3+ $\text{SrCl}_2$

Table B: Nuclear Moments by Paramagnetic Resonance — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	$\mu^1/\mu^2$	Valence and Lattice
$^{191}_{77}\text{Ir}$ $^{191}_{77}\text{Ir}$			+0.147 <sup>E</sup> 8		69Dall 70Sull	$^{191}_{193}=0.9165\ 3$ $^{191}_{193}=0.936\ 26$	4+ $(\text{NH}_4)_2\text{PtCl}_6$ at 4°K 4+ $\text{IrCl}_4$ in $\text{MgO}$ at 77°K, irradiated
$^{193}_{77}\text{Ir}$			+0.163 <sup>E</sup> 6		69Dall	$Q^{193}/Q^{191}=+0.92\ 9$	4+ $(\text{NH}_4)_2\text{PtCl}_6$ at 4°K
$^{197}_{79}\text{Au}$			+0.1453 <sup>E</sup> 4		60Wo02		0 (Cr,Au) doped Si
$^{231}_{91}\text{Pa}$ $^{231}_{91}\text{Pa}$	34ky 34ky	3/2 3/2	$\pm 1.98^{\circ}\ 2$		60Kyl 61Ax1		4+ $\text{PaCl}_4$ in $\text{Cs}_2\text{ZrCl}_6$ 4+ $\text{Cs}_2\text{ZrCl}_6$ crystal
$^{233}_{92}\text{U}$	162ky	5/2	$\pm 0.54$	$\pm 3.5\ 7$	57D40	$^{235}_{233}=\pm 0.651\ 2$ $Q^{235}/Q^{233}=\pm 1.17\ 20$ $\mu/Q=\pm 0.152\ 15$	3+ $\text{LaCl}_3$
$^{235}_{92}\text{U}$	710My	7/2	$\pm 0.38$ or $\pm 0.31$		56H26		3+ $\text{LaCl}_3$
$^{235}_{92}\text{U}$ $^{235}_{92}\text{U}$	710My 710My		+?0.35 $\pm 0.35$	-?3.8 8 $\pm 4.1$	56Bl29 57D40		3+ $\text{LaCl}_3$ and $^{235}\text{UCl}_3$ 3+ $\text{LaCl}_3$
$^{237}_{93}\text{Np}$	2.1My	5/2	$\pm 6.0\ 25$		54B73		$(\text{NpO}_2)^{2+}$ $\text{UO}_2\text{Rb}(\text{NO}_3)_3$
$^{237}_{93}\text{Np}$ $^{237}_{93}\text{Np}$	2.1My 2.1My		$\pm 2.70 \pm$ $\pm 3.2^{\circ}\ 9$ or $\pm 2.6^{\circ} \pm 7$		60Hu14 65Ei05	#Used $\langle r^{-3} \rangle = 50 \times 10^{24} \text{ cm}^{-3}$ Using $\langle r^{-3} \rangle = 50 \times 10^{24} \text{ cm}^{-3}$	$\text{UF}_6$ , $\text{NpF}_6$ $\text{Rb}(\text{NpO}_2)(\text{NO}_3)_3$
$^{237}_{93}\text{Np}$	2.1My		$\pm 2.1\ 4$		69Lell	$B/P < 0$ $A/P < 0$	$(\text{NpO}_2)^{2+}$ $\text{Cs}_2\text{UO}_2\text{Cl}_4$ at 4°K $\text{Cs}_2\text{UO}_2(\text{NO}_3)_3$ at 4°K
$^{239}_{93}\text{Np}$	2.3d	>1/2	$\pm 2.9\ 6$		58A18		$(\text{NpO}_2)^{2+}$ $\text{UO}_2\text{Rb}(\text{NO}_3)_3$
$^{239}_{94}\text{Pu}$	24ky	1/2	$\pm 0.4\ 2$		54B72	$^{241}_{239}=\pm 3.53\ 2$	$(\text{PuO}_2)^{2+}$ $\text{UO}_2\text{Rb}(\text{NO}_3)_3$
$^{239}_{94}\text{Pu}$	24ky	1/2			58A18		$(\text{PuO}_2)^{2+}$ $\text{UO}_2\text{Rb}(\text{NO}_3)_3$
$^{239}_{94}\text{Pu}$ $^{241}_{94}\text{Pu}$	24ky 13y				70Ko32 54B72	$^{249}_{239}=3.590^{\circ}\ 10$	3+ $\text{CaF}_2$ $(\text{PuO}_2)^{2+}$ $\text{UO}_2\text{Rb}(\text{NO}_3)_3$
$^{241}_{95}\text{Am}$	460y	5/2			68Ed01 67Ea04	$^{241}_{243}=1.0088\ 15$	2+ $\text{CaF}_2$ crystal
$^{241}_{95}\text{Am}$	460y				70Ab03	$^{241}_{243}=1.008\ 1$	2+ $\text{SrCl}_2$ crystal
$^{243}_{96}\text{Cm}$	28y	5/2	$\approx \pm 0.40 \pm$		73Ab03	$^{243}_{245}=0.79\ 1$ $^{243}_{247}=1.105\ 8$ Using $\mu(^{241}\text{Am})$ of 66Ar04. Not corrected for differences in $\langle r^{-3} \rangle$ between $\text{Am}^{2+}$ and $\text{Cm}^{3+}$ .	3+ $\text{SrCl}_2$ crystal at liquid He temperatures
$^{245}_{96}\text{Cm}$	8.26ky	7/2	$\pm 0.5 \pm 1$		70Ab03		3+ $\text{SrCl}_2$ crystal
$^{247}_{96}\text{Cm}$	15.4My	9/2	$\approx \pm 0.36 \pm$		73Ab03	$^{245}_{247}=1.41\ 1$ Using $\mu(^{241}\text{Am})$ of 66Ar04	3+ $\text{SrCl}_2$ crystal
$^{253}_{99}\text{Es}$	20.5d	7/2	$\pm 3.62\ 50$		71Ed04 70Ed02		2+ $\text{CaF}_2$ ; cubic sites

\* Polarization or Sternheimer correction included

c Recalculation of earlier data

E ENDOR (electron-nuclear double resonance) experiment

m Metastable or excited state

p Preliminary value from meeting abstract, thesis, private communication, etc.

**Table C: Nuclear Moments  
by Microwave Spectroscopy**

**Introduction**

The technique of microwave spectroscopy is used in the study of the pure rotational spectrum of gas molecules which usually are in the ground electronic state. The rotational states are split by the interaction of the nuclear electric quadrupole moment with the nonuniform molecular electric field at the nucleus.

One can infer the nuclear spin from the number, relative spacing, and relative intensities of the absorption lines observed in the microwave region. The spacing of the lines enables one to calculate the quadrupole coupling constant, from which the electric quadrupole moment can be determined. In view of the difficulties associated with calculating the electric field inhomogeneity and the effect of the polarization of the atomic electron core (Sternheimer

effect), the computed values of the quadrupole moment are subject to appreciable uncertainties. No attempt has been made here to evaluate these uncertainties.

If the substance being studied is placed in an external magnetic field, the rotational magnetic moments and the nuclear magnetic moment interact with this field giving rise to a Zeeman splitting in the spectrum from which  $\mu$  can be determined.

Detailed discussions of the technique can be found in *Microwave Spectroscopy*, W. Gordy, W. V. Smith, and R. F. Trambarulo [53Go38] and *Microwave Spectroscopy*, C. H. Townes and A. L. Schawlow [55To31]. Some of the more recent techniques and applications as well as general theory are described in *Microwave Molecular Spectroscopy* by W. Gordy and R. L. Cook [70Go50].

The last systematic literature search for information included in the table was in early 1971.

**Explanation of Table C**

Nucleus	Chemical symbol with Z- and A-numbers
$I$	Nuclear spin, in units of $h/2\pi$
$\mu$	Nuclear magnetic dipole moment, in nuclear magnetons, given with diamagnetic correction. See Policies, Diamagnetic corrections, for factors used
$Q$	Nuclear electric quadrupole moment, in barns, as given by the experimenter Values marked by an asterisk, *, indicate that the experimenter has made some polarization or Sternheimer correction in computing the moment.
Refer.	Reference key
$eqQ$ ratio	Ratio of the electric quadrupole coupling constants for the two nuclei indicated
$eqQ$	Electric quadrupole coupling constant in MHz When the quantity is enclosed in parentheses, ( ), the value has not been measured by the author quoted, but has been used by him to calculate the value of $Q$ .
Compound	Compound used

Table C: Nuclear Moments by Microwave Spectroscopy

Nucleus	<i>I</i>	$\mu$	<i>Q</i>	Refer.	<i>eqQ</i> ratio	<i>eqQ</i>	Compound
$^{10}_5\text{B}$	3		$\approx +0.06$	50G10	$^{10}_{11} = +2.17$	+3.36 10	$\text{BH}_3^{12}\text{CO}$
$^{10}_5\text{B}$	3			50W03		+3.44 1	$\text{H}_3^{10}\text{BCO}$
$^{11}_5\text{B}$	3/2		$\approx +0.03$	50G10		+1.55 8	$\text{BH}_3^{12}\text{CO}$
$^{14}_7\text{N}$	1			46C10		+10	$\text{NH}_3$
$^{14}_7\text{N}$	1		+0.02	48T10		-3.63 10	ClCN
$^{14}_7\text{N}$			+0.01	50S51		-7.07	$\text{NF}_3$
$^{14}_7\text{N}$			+0.0071 <sup>c</sup>	55B54		(+4.58 5)	HCN
$^{14}_7\text{N}$			+0.016 <sup>c</sup> 7	60Li10		<i>eqQ</i> =-1.7	NO
$^{14}_7\text{N}$			+0.0094 <sup>c</sup>	61Ka31		<i>eq'Q</i> =22 (-4.10)	ND <sub>3</sub>
$^{17}_8\text{O}$	5/2			52G26		-1.32 7	$^{17}\text{O}^{12}\text{C}^{32}\text{S}$
$^{17}_8\text{O}$	5/2			52M26			$^{16}\text{O}^{17}\text{O}$
$^{17}_8\text{O}$			-0.026 9	57S93		-8.1 1	HDO
$^{18}_8\text{O}$	0 <sup>d</sup>		<0.004	48T10		<1	OCS
$^{18}_8\text{O}$	0 <sup>d</sup>			51M20			$^{16}\text{O}^{18}\text{O}; ^{18}\text{O}_2$
$^{19}_9\text{F}$	1/2 <sup>d</sup>		<0.0003	49G28		<0.5	PF <sub>3</sub>
$^{28}_{14}\text{Si}$	0 <sup>d</sup>			49T09			SiH <sub>3</sub> Cl
$^{29}_{14}\text{Si}$	1/2 <sup>d</sup>		<0.0001	53W39		<0.05	SiD <sub>3</sub> F
$^{30}_{14}\text{Si}$	0 <sup>d</sup>			49T09			SiH <sub>3</sub> Cl
$^{31}_{15}\text{P}$	1/2 <sup>d</sup>			49G28			PF <sub>3</sub>
$^{33}_{16}\text{S}$	3/2		$-0.05^{+5}_{-3}$	48T13		-28.5 7	OCS
$^{33}_{16}\text{S}$	3/2	+0.634 10		52E07		-29.07 1	$^{16}\text{O}^{12}\text{C}^{33}\text{S}$
$^{33}_{16}\text{S}$			-0.06*	53B92		+40	H <sub>2</sub> S
$^{33}_{16}\text{S}$			-0.058 10	54B40			Several
$^{33}_{16}\text{S}$			-0.056 <sup>c</sup>	62Ko22			
				(54B40)			
$^{34}_{16}\text{S}$	0 <sup>d</sup>		<0.002	48T10		<1	OCS
$^{35}_{16}\text{S}$	3/2		+0.06 <sup>+6</sup> <sub>-3</sub>	51W11	$^{33}_{35}$ negative	+20.5 2	OCS
$^{35}_{16}\text{S}$		+1.00 or -1.07 4		54B05		+21.90 4	OCS
$^{35}_{16}\text{S}$			+0.045* 10	54B40	$(^{35}_{33} = -0.695)$		Several
$^{36}_{16}\text{S}$	0 <sup>d</sup>		<0.01	49L21		<5	OCS
$^{35}_{17}\text{Cl}$	3/2		-0.077	48T10			Several
				49T17			
$^{35}_{17}\text{Cl}$				49G25	$^{35}_{37} = +1.2704 4$	-145.94 26	FCl
$^{35}_{17}\text{Cl}$				50S56	$^{35}_{37} = +1.2768 40$	-103.60 15	BrCl
$^{35}_{17}\text{Cl}$				51G06	$^{35}_{37} = 1.2670 5$		GeH <sub>3</sub> Cl
					$^{35}_{37} = +1.2682 6$		ClCN
					$^{35}_{37} = +1.2691 3$		CH <sub>3</sub> Cl
$^{36}_{17}\text{Cl}$	2		-0.0172 4	49T10			$^{36}\text{Cl}^{12}\text{C}^{14}\text{N}$
$^{36}_{17}\text{Cl}$	2		-0.0168 1	51J21		-15.87 9	CH <sub>3</sub> Cl
$^{36}_{17}\text{Cl}$	2		-0.0164 8	52G04		-15.6 6	CH <sub>3</sub> <sup>36</sup> Cl
$^{36}_{17}\text{Cl}$	2	+1.31 8		55A23	$g^{36}/g^{35} = \pm 1.20 7$	-15.83 20	CH <sub>3</sub> <sup>36</sup> Cl
$^{37}_{17}\text{Cl}$	3/2		-0.061	48T10		-65.7 5	$^{37}\text{Cl}^{12}\text{C}^{14}\text{N}$
$^{37}_{17}\text{Cl}$				49G25		-114.92 26	FCl
$^{55}_{25}\text{Mn}$	5/2		+0.55 <sup>+50</sup> <sub>-25</sub>	54J16		+16.8	MnO <sub>3</sub> F
$^{69}_{31}\text{Ga}$				70Ho23	$^{69}_{71} = 1.5871 10$	-107.07 8	$^{69}\text{GaF}$
$^{71}_{31}\text{Ga}$				70Ho23		-67.46 8	$^{71}\text{GaF}$

Table C: Nuclear Moments by Microwave Spectroscopy — Continued

Nucleus	<i>I</i>	$\mu$	<i>Q</i>	Refer.	<i>eqQ</i> ratio	<i>eqQ</i>	Compound
$^{70}_{32}\text{Ge}$	0 $^+$		<0.007	49T09			$\text{GeH}_3\text{Cl}$
$^{72}_{32}\text{Ge}$	0 $^+$		<0.007	49T09			$\text{GeH}_3\text{Cl}$
$^{73}_{32}\text{Ge}$	9/2		-0.21 10	49T09			$\text{GeH}_3\text{Cl}$
$^{73}_{32}\text{Ge}$			-0.21 <sup>c</sup>	62Ko22 (49T09)		-95 3	$\text{GeH}_3\text{Cl}$
$^{74}_{32}\text{Ge}$	0 $^+$		<0.007	49T09			$\text{GeH}_3\text{Cl}$
$^{76}_{32}\text{Ge}$	0 $^+$		<0.007	49T09			$\text{GeH}_3\text{Cl}$
$^{75}_{33}\text{As}$	3/2			48D08		-235	$\text{AsF}_3$
$^{74}_{34}\text{Se}$	0 $^+$			49S07		<0.5	$\text{OCSe}$
$^{74}_{34}\text{Se}$	0 $^+$		<0.002	50G05			$\text{OCSe}$
$^{75}_{34}\text{Se}$	5/2		+1.1 2	55A06	$^{75}/_{19} = +1.25783\ 62$	+946.0	$\text{OC}^{75}\text{Se}$
$^{76}_{34}\text{Se}$	0 $^+$			49S07		<0.5	$\text{OCSe}$
$^{76}_{34}\text{Se}$	0 $^+$		<0.002	50G05			$\text{OCSe}$
$^{77}_{34}\text{Se}$	1/2 $^+$			49S07		<0.5	$\text{OCSe}$
$^{77}_{34}\text{Se}$	1/2 $^+$		<0.002	50G05		<1.0	$\text{OCSe}$
$^{78}_{34}\text{Se}$	0 $^+$			49S07		<0.5	$\text{OCSe}$
$^{78}_{34}\text{Se}$	0 $^+$		<0.002	50G05			$\text{OCSe}$
$^{79}_{34}\text{Se}$	7/2	-1.018 15	+0.7 2	53H50		+752.09 5	$\text{OCSe}$
$^{79}_{34}\text{Se}$			+0.9* 2	54B40		(752.09)	$\text{OCSe}$
$^{79}_{34}\text{Se}$			+0.8 <sup>c</sup>	62Ko22 (54B40)			
$^{80}_{34}\text{Se}$	0 $^+$			49S07		<0.5	$\text{OCSe}$
$^{80}_{34}\text{Se}$	0 $^+$		<0.002	50G05			$\text{OCSe}$
$^{82}_{34}\text{Se}$	0 $^+$			49S07		<0.5	$\text{OCSe}$
$^{82}_{34}\text{Se}$	0 $^+$		<0.002	50G05			$\text{OCSe}$
$^{79}_{35}\text{Br}$			+0.28	48G25	$^{79}/_{81} = +1.197$	+686.0	$\text{BrCN}$
$^{79}_{35}\text{Br}$			+0.24		$^{79}/_{81} = +1.197$	+577.0	$\text{CH}_3\text{Br}$
$^{79}_{35}\text{Br}$	3/2		+0.28	48T10		+686.5 5	$\text{BrCN}$
$^{79}_{35}\text{Br}$				50S56	$^{79}/_{81} = +1.1963\ 14$	+876.8 9	$\text{BrCl}$
$^{79}_{35}\text{Br}$			+0.31	51G37			Several
$^{79}_{35}\text{Br}$				54R43	$^{79}/_{81} = +1.19711\ 12$		$\text{PBr}_2$
$^{81}_{35}\text{Br}$			+0.23	48G25	$^{79}/_{81} = 1.197$	+573.0	$\text{BrCN}$
$^{81}_{35}\text{Br}$			+0.19			+482.0	$\text{CH}_3\text{Br}$
$^{81}_{35}\text{Br}$	3/2		+0.23	48T10		+573.5 5	$\text{BrCN}$
$^{81}_{35}\text{Br}$				50S56		+732.9 5	$\text{BrCl}$
$^{81}_{35}\text{Br}$			+0.26	51G37			Several
$^{115}_{49}\text{In}$				70Ho23	$^{115}/_{113} = 1.0139\ 4$		$^{115}\text{InF}$
$^{121}_{51}\text{Sb}$	5/2			51L24	$^{121}/_{123} = +0.791$	-455	$\text{SbH}_2\text{D}$
$^{121}_{51}\text{Sb}$			-0.8 <sup>+1</sup> <sub>-6</sub>	55J30	$^{121}/_{123} = 0.784\ 2$	458.7 8	$\text{SbH}_3$
$^{123}_{51}\text{Sb}$	7/2			51L24		465.4 8	$\text{SbD}_3$
$^{123}_{51}\text{Sb}$				55J30		-575	$\text{SbH}_2\text{D}$
$^{123}_{51}\text{Sb}$			-1.0 <sup>+1</sup> <sub>-8</sub>			586.0 8	$\text{SbH}_3$
$^{123}_{51}\text{Sb}$						592.8 8	$\text{SbD}_3$
$^{125}_{53}\text{I}$	5/2	$\pm 3.0\ 10$	-0.89 <sup>b</sup>	58F39	$^{125}/_{127} = 1.127$	-2179 1	$\text{CH}_3^{125}\text{I}$
$^{127}_{53}\text{I}$	5/2		-0.59	48G25		-1934	$\text{CH}_3\text{I}$
$^{127}_{53}\text{I}$		$\pm 2.807$		49G19			$\text{CH}_3\text{I}$
$^{127}_{53}\text{I}$			-0.75	49T17			Several
$^{127}_{53}\text{I}$			-0.65	51G37			Several
$^{129}_{53}\text{I}$		$\pm 2.74\ 14$		49G19			$\text{CH}_3\text{I}$
$^{129}_{53}\text{I}$	7/2		-0.58 <sup>b</sup>	49L09	$^{129}/_{127} = +0.7353$	-1422	$\text{CH}_3\text{I}$
$^{129}_{53}\text{I}$			-0.47 <sup>c</sup>	51G37			

**Table C: Nuclear Moments by Microwave Spectroscopy — Continued**

Nucleus	<i>I</i>	$\mu$	<i>Q</i>	Refer.	<i>eqQ</i> ratio	<i>eqQ</i>	Compound
$^{131}_{53}\text{I}$	7/2		-0.40 <sup>b</sup>	53L24	$^{131}_{127} = +0.5031$	-973 9	$\text{CH}_3^{131}\text{I}$
$^{131}_{53}\text{I}$	7/2	+2.56 12	-0.40	58F39	$^{131}_{127} = +0.5036$	-974 1	$\text{CH}_3\text{I}$
$^{185}_{75}\text{Re}$	5/2		+2.8	54J16	$^{185}_{187} = +1.067\ 45$	+270 6	$\text{ReO}_3\text{Cl}$
$^{187}_{75}\text{Re}$	5/2			54J16		+253 6	$\text{ReO}_3\text{Cl}$

<sup>a</sup> Polarization or Sternheimer correction included<sup>b</sup> No hyperfine structure observed<sup>c</sup> Do not see *K*=8, 6, and 4 lines of  $^{16}\text{O}_2$  spectrum, which indicates the spin is zero<sup>b</sup> Calculated from *eqQ*-ratio and  $Q^{127}=0.79$  as measured by atomic beams<sup>c</sup> Recalculation of earlier data

**Table D: Nuclear Moments  
by Quadrupole Resonance**

### Introduction

In a diamagnetic molecule or crystal, a nucleus possessing an electric quadrupole moment will interact with a nonuniform electric field arising from the charge distribution of its environment. This interaction causes a splitting of electronic energy levels resulting from the possible orientations of the nuclear spin with respect to a reference axis. For an electric field with axial symmetry, the levels for  $+m_I$  and  $-m_I$  are degenerate and the spacing between levels with  $m_I = \pm I, \pm (I-2) \dots$  is given by  $[3eqQ/4I(2I-1)] \cdot (2I-1)$ ,  $(2I-3) \dots$ , where  $m_I$  is the projection of  $I$  on the axis and  $q$  is the electric field gradient at the nucleus. Transitions between the levels can be induced and detected by radio-frequency absorption techniques similar to those used in magnetic resonance. The values of the quadrupole coupling constants can be determined from the resonant frequencies.

Ratios of quadrupole moments of two isotopes can be obtained quite accurately from the ratios of the

resonant frequencies for the respective isotopes. The determination of the quadrupole moment from the coupling constant depends upon a calculation of the field inhomogeneity at the nucleus which may be uncertain by a few percent. In addition, the nuclear electric quadrupole moment causes a polarization of the atomic core electrons (Sternheimer effect) which can affect the evaluation of the field gradient by tens of percent.

In several cases the magnetic dipole moment has been determined from the Zeeman splitting of the quadrupole resonance which is produced when the sample is placed in a strong external magnetic field.

Details of this method are described by Krüger [51Kr51] and Dehmelt [53De42]. A discussion of the theory and instrumentation of nuclear quadrupole resonance spectroscopy and its application to solid state physics as well as tables of interaction constants for several elements in many compounds can be found in Das and Hahn [58Da20]. Tables of quadrupole interaction constants can be found in [68Se12] and [69Lu11].

The last systematic literature search for information included in the table was in early 1971.

### Explanation of Table D

Nucleus	Chemical symbol with $Z-$ and $A-$ number
$\mu$	Nuclear magnetic dipole moment, in nuclear magnetons, given with diamagnetic correction See Policies, Diamagnetic corrections, for factors used
$Q$	Nuclear electric quadrupole moment, in barns, as given by the experimenter Values marked by an asterisk, *, indicate that the experimenter has made some polarization or Sternheimer correction in computing the moment.
Refer.	Reference key
$eqQ$ ratio	Ratio of the electric quadrupole coupling constants for the two isotopes noted
$eqQ$	Electric quadrupole coupling constant in MHz
Compound	Compound used

Table D: Nuclear Moments by Quadrupole Resonance

Nucleus	$\mu$	$Q$	Refer.	$eqQ$ ratio	$eqQ$	Compound
$^{10}_5\text{B}$		+0.111*	53D13	$^{10}/_{11}=2.084$ 2	10.31	$\text{BC}_3$
$^{11}_5\text{B}$		$\pm 0.05$	53B91		(4.87)	$\text{B}(\text{CH}_3)_3$
$^{11}_5\text{B}$		+0.053*	53D13		4.95	$\text{BC}_3$
$^{33}_{16}\text{S}$		-0.050	53D16		45.8	$\text{S}_8$ (rhombic)
$^{35}_{16}\text{S}$		+0.035	53D16	$(^{35}/_{33}=-0.695 \text{ Mic})$		
$^{35}_{17}\text{Cl}$			51D13	$^{35}/_{37}=1.2688$ 2	37.5	$\text{CHCl}=\text{CHCl}$
$^{35}_{17}\text{Cl}$			51L09	$^{35}/_{37}=1.26878$ 15		5 compounds
$^{35}_{17}\text{Cl}$	$\pm 0.8224$ 10		53T29			$\text{NaClO}_3$
$^{35}_{17}\text{Cl}$			55W24	$^{35}/_{37}=1.268736$ to 1.268973		4 compounds at several temp.
$^{35}_{17}\text{Cl}$			66Ca15	$^{35}/_{37}=1.2685$ 3		$\text{GdCl}_3$ (ferromagnetic)
$^{35}_{17}\text{Cl}$			70Ka25	$^{35}/_{37}=1.26877$ 3		$\text{LiClO}_3$ dried
$^{37}_{17}\text{Cl}$			51D13		29.5	$\text{CHCl}=\text{CHCl}$
$^{40}_{19}\text{K}$		$\pm 0.066^*\pm 0.010$	69Jo06	$^{40}/_{39}=1.244^d$ 2		$^{40}\text{KClO}_3$ crystal
$^{63}_{29}\text{Cu}$			52K29	$^{63}/_{65}=1.0806$ 3	65.3	$\text{KCu}(\text{CN})_2$
$^{63}_{29}\text{Cu}$	$\pm 2.231$ 7		57C48	$^{63}/_{65}=1.0811$ 12	51.96 4	$\text{Cu}_2\text{O}$
$^{63}_{29}\text{Cu}$			66De17	$^{63}/_{65}=1.0806$ 6		$\text{Cu}_2\text{O}$
$^{65}_{29}\text{Cu}$	$\pm 2.382$ 7		57C48		48.06 4	$\text{Cu}_2\text{O}$
$^{69}_{31}\text{Ga}$			53D22	$^{69}/_{71}=1.5867$ 4	58.120 4	$\text{GaCl}_3$
$^{69}_{31}\text{Ga}$			56K66	$^{69}/_{71}=1.589$ 2		Ga metal
$^{71}_{31}\text{Ga}$			53D22		36.630 4	$\text{GaCl}_3$
$^{75}_{33}\text{As}$	$\pm 1.44$ 3		52K28		232.52 4	$\text{As}_4\text{O}_6$
$^{79}_{35}\text{Br}$		$\pm 0.30$	51D16	$^{79}/_{81}=1.1968$ 2	764.86 8	$\text{Br}_2$ (crystal)
$^{79}_{35}\text{Br}$			53K22	$^{79}/_{81}=1.1970$ 1	497.0	$\text{C}_2\text{H}_5\text{Br}$
$^{79}_{35}\text{Br}$			54Sc10	$^{79}/_{81}=1.19707$ 3		average for 6 compounds
$^{81}_{35}\text{Br}$		$\pm 0.25$	51D16		638.92 6	$\text{Br}_2$ (crystal)
$^{121}_{51}\text{Sb}$			51D15	$^{123}/_{121}=1.2751^*$ 2	383.66* 4	$\text{SbCl}_3$
$^{121}_{51}\text{Sb}$			55W24	$^{123}/_{121}=1.274745$ 10	321.93223	$\text{SbBr}_3$
				$Q_4^{123}/Q_4^{121}\sim 0.8$ 3	$eq_4Q_4=0.030$ 5	
					$eqQ/eq_4Q_4<0$	
$^{121}_{51}\text{Sb}$			57O11	$^{123}/_{121}=1.274755$ 2	551.3822 5	$\text{Sb}_2\text{O}_3$
				$Q_4^{123}/Q_4^{121}\sim 1.5$ 10	$eq_4Q_4=0.012$ 5	
$^{121}_{51}\text{Sb}$			63He02	$^{123}/_{121}=1.27492$ 2	76.867 1	powdered Sb
$^{123}_{51}\text{Sb}$			51D15		489.21* 5	$\text{SbCl}_3$
$^{123}_{51}\text{Sb}$			55W24		410.3814	$\text{SbBr}_3$
					$eq_4Q_4=0.024$ 5	
					$eqQ/eq_4Q_4<0$	
$^{123}_{51}\text{Sb}$			57O11		702.8773 5	$\text{Sb}_2\text{O}_3$
					$eq_4Q_4=0.018$ 10	
$^{123}_{51}\text{Sb}$			63He02		97.999 1	powdered Sb
					$eq_4Q_4=+0.013$ 30	
$^{127}_{53}\text{I}$		$\pm 0.69^*$	52K43		2156*	solid $\text{I}_2$
$^{127}_{53}\text{I}$			53L16	$^{127}/_{129}=1.42610$ 3	1389.678(site A)	$\text{SnI}_4$
					1399.949(site B)	
$^{129}_{53}\text{I}$		$\pm 0.55^b$	53L16	$^{127}/_{129}=1.42610$ 3	974.481 (site A) 981.654 (site B)	$\text{SnI}_4$

**Table D: Nuclear Moments by Quadrupole Resonance — Continued**

Nucleus	$\mu$	$Q$	Refer.	$eqQ$ ratio	$eqQ$	Compound
$^{133}_{55}\text{Cs}$		$Q_4 < 100^{\text{E}}$ b <sup>2</sup>	67Tz01			CsI
$^{135}_{56}\text{Ba}$			62Wi10	$^{137}_{135} = 1.543\ 3$		$\text{BaBr}_2 \cdot 2\text{H}_2\text{O}$
$^{135}_{56}\text{Ba}$	$\pm 0.840$		63Na11	$^{137}_{135} = 1.542\ 2$	8.55 1	$\text{Ba}(\text{ClO}_3)_2 \cdot \text{H}_2\text{O}$
$^{137}_{56}\text{Ba}$	$\pm 0.944$		63Na11	$\mu^{137}/\mu^{135} = 1.123$	$\gamma/\gamma_{\text{H}} = 0.0997$ 13.18 1 $\gamma/\gamma_{\text{H}} = 0.112$	$\text{Ba}(\text{ClO}_3)_2 \cdot \text{H}_2\text{O}$
$^{185}_{75}\text{Re}$			57S32	$^{185}_{187} = +1.056\ 5$		$\text{Re}_2(\text{CO})_{10}$
$^{185}_{75}\text{Re}$			68Se09	$^{185}_{187} = 1.0565\ 3$		7 compounds
$^{185}_{75}\text{Re}$			70Bu09	$^{185}_{187} = 1.059^{\text{E}}\ 14$		Rh metal crystal
$^{201}_{80}\text{Hg}$	$\pm 0.6$		54D01		720	$\text{HgCl}_2$
$^{209}_{83}\text{Bi}$			53R33		669.06 13	$\text{Bi}(\text{C}_6\text{H}_5)_3$

\* Polarization or Sternheimer correction included

\* Corrected for non-rotationally symmetric field

b Calculated from  $eqQ$ -ratio and  $Q^{127}=0.79$  as measured by atomic beams

c Recalculation of earlier data

d Double resonance experiment

e Nuclear acoustic resonance experiment

**Table E: Nuclear Moments by Nuclear Magnetic Resonance****Introduction**

A nucleus with spin  $I$  and an associated magnetic moment  $\mu$ , when placed in a magnetic field  $H_0$ , will precess so that its spin axis rotates about  $H_0$  with a (Larmor) frequency

$$\nu_L = \mu H_0 / hI.$$

If the nucleus is in a medium (gas, liquid, or solid) which does not contain a large concentration of unpaired electrons, then the field due to the neighboring atoms is small compared to the value of  $H_0$ , which is generally of the order of several kilogauss. The field  $H_0$  will cause a splitting of the ground state into  $2I + 1$  magnetic states, separated in energy by  $\mu H_0/I$ , with relative population given by the Boltzmann distribution function characteristic of the temperature of the sample. The application of a rotating field  $H_1$ , perpendicular to  $H_0$ , induces transitions between the levels when its frequency resonates with the Larmor frequency. Because of the differences in level occupation, there is a net absorption of energy from the field  $H_1$  at frequency  $\nu_L$ . This absorption can be observed electronically.

In order that this method be applicable, not only must the sample be diamagnetic, but also: 1) the spin-lattice relaxation time, i.e., the time taken for the spin system to come into approximate thermal equilibrium with the lattice, must be a reasonable figure (0.1 to 0.001 s); 2) the nuclear interaction should be free from large electric quadrupole effects; 3) the spin density should be high enough so that a reasonable signal can be observed. In practice this might mean  $10^{18}$  to  $10^{20}$  spins in a volume of 0.1 to 1 cc in a field of about  $10^4$  gauss.

The precision with which nuclear magnetic resonance frequencies have been measured ranges up to a few parts in  $10^7$ . The corresponding nuclear magnetic moments, however, are known to a much lower precision. The uncertainty is introduced in part because of two small contributions to the effective magnetic field at the nucleus which cannot be precisely evaluated.

The effective field can be expressed as

$$H_{\text{eff}} = H_0 + H' + H'' = H_0(1 + H'/H_0 + H''/H_0),$$

where  $H_0$  is the externally applied field,  $H'$  is the diamagnetic effect due to the currents induced in the atomic electrons by the external field, and  $H''$  is the contribution due to the molecular environment.

Prior to any precise measurements of nuclear resonance,  $H'/H_0$  was evaluated (approximately) by Lamb [41La03] by means of a simple calculation based upon the Fermi-Thomas model. This

calculation was extended by Dickinson [50Di10] using Hartree-Fock functions. No account was taken of relativity or other possible high-order corrections. Dickinson had estimated that the accuracy of the correction was about 5%. Since this correction varies from about 0.2% for hydrogen to about 1.2% for uranium, the quoted uncertainty in the tabulated value of  $\mu$  is, in many cases, due to the uncertainty in the diamagnetic correction. Newer calculations based on Hartree-Fock relativistic electron wavefunctions show these earlier values of the diamagnetic correction are too small. They differ by about 1% at low  $Z$ , while for  $Z$  about 90, they are off by a factor of two. Diamagnetic correction factors for some closed-shell and closed sub-shell ions can be found in a paper by Feiok and Johnson [68Fe05]. Average correction factors for neutral atoms have been calculated by Lin, Johnson and Feiok [72Jo18]. These values take into account the contributions of the closed-shell core of the atom and an average shielding for the valence electrons in the ground state configuration. This average is made over the ground state multiplet assigning statistical weights to the sub-shells. Such average diamagnetic correction factors do not include possible large contributions for individual valence electrons. Values of the diamagnetic correction factors,  $(1-\sigma)^{-1} = (1+H'/H_0)^{-1}$ , used in the tables are tabulated under Diamagnetic Corrections (see Policies) along with the newer calculated values of Lin, Johnson and Feiok.

The term  $H''/H_0$ , the so-called "chemical shift," is associated with the induced field in the molecular environment. This effect has been evaluated theoretically in only a few simple cases. If the magnetic moment can be measured in a free atom in a well defined state, such as by atomic beams or optical double resonance, the value of  $H''/H_0$  can be determined empirically. While differences in  $H''/H_0$  between different compounds have been observed to be as high as  $10^{-2}$ , the more common values appear to be near  $10^{-4}$  (see Walchli [53W63]). In addition, in aqueous solutions  $H''$  may also be a function of concentration. Much work has been done recently by Lutz, Schwenk and collaborators at Tübingen on the effect of concentrations and of added paramagnetic salts on the resonance frequency in aqueous solutions. For example, see [67Lu06], [67Lu10], and [68Lu07]. In the table, no attempt has been made to consider quantitatively the chemical effects. Therefore, the significance of any limits of precision for the magnetic moments stated to less than  $10^{-4}$ , except for the very light elements, should be questioned.

In view of the difficulty of measuring the absolute value of  $H$ , the tabulated value of  $\mu_s$  of the nucleus has been calculated by use of the relation

$$\mu_s = \mu'_p (\nu_a/\nu_b)(\nu_b/\nu_p)(I_a/I_p)(1 + H'/H_0)_a^{-1},$$

where the subscript "a" refers to the nucleus under consideration, "p" to the proton, and "b" to a reference standard. The value used for  $\mu'_p$  for a spherical water sample, 2.79270, is the weighted average of the values of Bloch and Jeffries [50Bl73], Sommer et al. [51So34], Collington et al. [55Co36], and Trigger [56Tr19], whose experiments yield the magnetic moment directly in nuclear magnetons without application of correction factors. Our value agrees well with the value  $\nu'_p = 2.79268 \pm 2$  (for a proton in water) in the adjustment of Cohen and DuMond [65Co20]. Newer measurements, see [73CoTa], indicate that the magnetic moment of the proton, measured directly in nuclear magnetons for a spherical sample of water, should be increased to 2.7927740  $\pm 11$ , well outside the previously quoted uncertainties.

Values of the frequency ratios,  $\nu_b/\nu_p$ , which were adopted in order to calculate the magnetic moments from relative measurements, are tabulated below:

$^2\text{H}$	0.15350609 $\pm 2$	$^{45}\text{Sc}$	0.24291623 $\pm 10$
$^7\text{Li}$	0.38863618 $\pm 8$	$^{50}\text{V}$	0.0997015 $\pm 10$
$^{11}\text{B}$	0.3208377 $\pm 2$	$^{55}\text{Mn}$	0.24789167 $\pm 6$
$^{14}\text{N}$	0.07226261 $\pm 1$	$^{73}\text{Ge}$	0.03488401 $\pm 14$
$^{23}\text{Na}$	0.26451775 $\pm 7$	$^{85}\text{Rb}$	0.096552095 $\pm 54$
$^{27}\text{Al}$	0.26056752 $\pm 7$	$^{127}\text{I}$	0.200080 $\pm 14$
$^{35}\text{Cl}$	0.09797858 $\pm 5$	$^{199}\text{Hg}$	0.178788 $\pm 15$ (NMR) 0.1782706 $\pm 3$ (OP)
$^{39}\text{K}$	0.0466636 $\pm 7$		
$^{41}\text{K}$	0.02561295 $\pm 12$		

†From a least squares adjustment for the  $g$ -factors for  $^2\text{H}$ ,  $^7\text{Li}$ ,  $^{23}\text{Na}$  with  $g'_p=5.58540$  fixed.

\*Weighted average.

These were calculated from the measured ratios which are marked with a † in the table. A least squares adjustment was made for  $g'(^2\text{H})$ ,  $g'(^7\text{Li})$ , and  $g'(^{23}\text{Na})$  with  $g'_p=5.58540$  fixed. The other values are either weighted averages of the measured ratios or particular measured ratios. A diagram of the most precisely measured frequency ratios between pairs of these isotopes is given in figure 1. The intensity of the line joining the isotopes represents the relative uncertainty of the measured frequency ratios.

In the calculation of the nuclear magnetic moments, no error in the value of  $\mu'_p$  was assumed. The uncertainties quoted in the tabulated moments represent a composite of uncertainties in the experimental values, conversion factors, standard frequency ratios, and the assumed 5% uncertainty in the diamagnetic corrections.

While the technique of nuclear resonance is primarily useful for the determination of the ratio  $\mu_g/I$ , in some cases it is possible to determine the value of the nuclear spin. If the electric quadrupole interaction in a single crystal is of the right order of magnitude, the magnetic resonance line may be split into  $2I$  components. If these are clearly resolved, then the spin and electric quadrupole interaction,  $eqQ$ , can be determined unambiguously. Several spins have been measured or confirmed in this way. The width and intensity of a resonance line in a polycrystalline or noncrystalline medium is related to the nuclear spin. In principle, therefore, the spin can be determined from measurements of line shape. However, distortions due to power saturation and field inhomogeneities subject these measurements to some

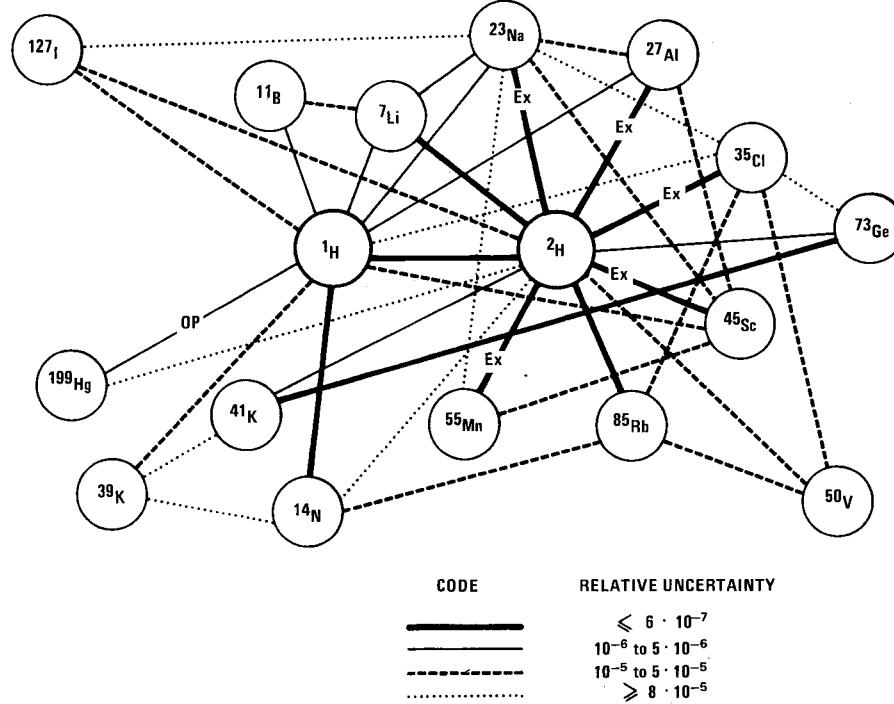


FIGURE 1. Diagram of relative uncertainties of the more precise frequency ratios for the ground states of the corresponding isotopes. The ratios for those connections marked with "Ex" have been determined by extrapolation to zero concentration. The connection marked with "OP" represents an optical pumping measurement.

question. The electric quadrupole moments listed in this table have been determined either by splitting of the resonance line in a single crystal or by line broadening in a noncrystalline medium.

In preparing the table, the compilers omitted data with accuracy about an order of magnitude less than that of the other values available.

Detailed discussions of these techniques can be found in Bloembergen et al. [48Bl32], Pound and Knight [50Po15], Andrew [55An65], Pake [56Pa60], Abragam [61Ab08], and Slichter [63Sl03] as well as in the references given in the general introduction.

The last systematic literature search for information included in the table was in early 1971.

### Explanation of Table E

Nucleus	Chemical symbol with $Z-$ and $A-$ number
$I$	Nuclear spin, in units of $h/2\pi$ Values not measured but assumed in order to calculate $\mu$ are enclosed in brackets, [ ].
$\mu$	Nuclear magnetic dipole moment, in nuclear magnetons, given with diamagnetic correction. See Policies, Diamagnetic corrections, for factors used Moment values which have been obtained by combining optical pumping or nuclear alignment with NMR have been tabulated here as well as in Tables H or J, respectively.
	Uncorrected magnetic dipole moment values, based on adopted frequency ratios quoted above, have also been tabulated along with a reference to the procedure used to obtain the ratio.
Diam. Cor.	Diamagnetic correction in nuclear magnetons $\times 10^4$ which has been added to the observed magnetic moment to give value quoted in table The uncertainty in the diamagnetic correction is assumed to be 5%.
$Q$	Nuclear electric quadrupole moment, in barns, as given by experimenter
Refer.	Reference key
$\nu/\nu'_{\text{standard}}$	Ratio of the measured resonance frequency for the nucleus under consideration to that of a standard nucleus Values marked with a † were used to obtain adopted frequency ratios above.
Standard	Nucleus used as standard
Chemical Forms	Chemical formulae of substances containing the nuclide under consideration and the standard The formulae have been separated by a plus sign when the substances were physically mixed and by a semicolon when they were in separate samples.

Table E: Nuclear Moments by Nuclear Magnetic Resonance

Nucleus	$T_{1/2}$	$I$	$\mu$	Diam. Cor. (nm $\times 10^4$ )	$Q$	Refer.	$\nu/\nu'$ standard	Stan-dard	Chemical Forms
$\mu^+$			$\pm 8.89013^r 2$			70Ha74	3.183347 9	$^1\text{H}$	$\text{NaOH} + \text{H}_2\text{O}; \text{H}_2\text{O}; \text{CH}_2(\text{CN})_2$
$\mu^+$			$\pm 8.89009^r 12$			70Hu19	3.183330 44	$^1\text{H}$	spherical sample $\text{H}_2\text{O}$
$^2\text{H}$		1	$+0.857415 4$	0.24		50L06	0.15350585 75	$^1\text{H}$	$\text{D}_2\text{O}; \text{H}_2\text{O}$
$^2\text{H}$			$\pm 0.857416 1$	0.24		51S72	$\pm 0.153506083 60$	$^1\text{H}$	$\text{D}_2\text{O} + \text{H}_2\text{O}$
$^2\text{H}$			$\pm 0.857417 1$	0.24			$\pm 0.153506125 50$	$^1\text{H}$	$\text{D}_2 + \text{H}_2$
$^2\text{H}$			$\pm 0.857420 1$	0.24		52L18	$\pm 0.15350668 12$	$^1\text{H}$	$\text{D}_2\text{O}; \text{H}_2\text{O}$
$^2\text{H}$			$\pm 0.857416 1$	0.24		53W23	$\pm 0.153506096 8$	$^1\text{H}$	$\text{HD}$
$^2\text{H}$			$\pm 0.857415 1$	0.24		61Bo11	$\pm 0.15350581 7$	$^1\text{H}$	$\text{D}_2\text{O}; \text{H}_2\text{O}$
$^2\text{H}$			$\pm 0.85739292^1 14$	—		Adj.	0.15350609 2	$^1\text{H}$	Least squares adj. of $^2\text{H}$ , $^7\text{Li}$ , and $^{23}\text{Na}$ ratios
$^3\text{H}$	12y		$\pm 2.97894 30$	0.83		47A09	1.06666 10	$^1\text{H}$	$\text{T}_2\text{O} + \text{H}_2\text{O}$
$^3\text{H}$	12y	1/2	$+2.978877 30$	0.83		47B32	1.066636 10	$^1\text{H}$	$\text{T}_2\text{O}; \text{H}_2\text{O}$
$^3\text{H}$	12y		$\pm 2.978887 4$	0.83		59D80	1.06663975 2	$^1\text{H}$	$\text{T}_2\text{O}; \text{H}_2\text{O}; \text{HTO}$
$^3\text{H}$	12y		$\pm 2.978860 4$	0.83		65Hu13	1.0666315 30	$^1\text{H}$	0.5% $\text{T}_2\text{O}$ at 23.5, 10800G
							1.0666298 5	$^1\text{H}$	
$^3\text{He}$	1/2		$\pm 2.127569 7$	1.28		49A11	0.7617866 12	$^1\text{H}$	$^3\text{He} + \text{H}_2 + \text{O}_2$
$^3\text{He}$			negative			57K31		$^3\text{He}; \text{H}_2\text{O}$	
$^3\text{He}$			$\pm 2.127574 \pm 1$	1.28		69Wi19	0.76178685 8	$^1\text{H}$	$\text{He} + \text{H}_2 + \text{O}_2$ at 10 to 30 atmospheres
							0.76181237 $\pm 46$	$^1\text{H}$	
									‡Used $\sigma(^3\text{He}) = 59.935$ and $\sigma(\text{H}_2) = 26.43$ 60ppm
$^6\text{Li}$			$\pm 0.822030 4$	0.83		51A27	0.37865725 72	$^7\text{Li}$	$\text{LiCl}$
$^6\text{Li}$	1			$\pm 4.6 \times 10^{-4q}$		51S07	$Q^6/Q^7 = 0.023^q 2$	$^7\text{Li}$	$\text{LiAl}(\text{SiO}_3)_2$ single crystal
$^6\text{Li}$			$\pm 0.822030 5$	0.83		51W24	0.3786573 15	$^7\text{Li}$	$\text{LiCl}$
$^6\text{Li}$						53C40	$Q^6/Q^7 = 0.019^q 1$	$^7\text{Li}$	$\text{LiAl}(\text{SiO}_3)_2$
$^6\text{Li}$			$+0.822012 33$	0.83		54W37	0.958638 38	$^2\text{H}$	$\text{LiCl} + \text{D}_2\text{O}$
$^6\text{Li}$			$\pm 0.822031 4$	0.83		67Lu06	0.9586599 <sup>E</sup> 3	$^2\text{H}$	$\text{LiCl} + \text{D}_2\text{O}$
$^7\text{Li}$			$\pm 3.25613 17$	3.3		49S56	0.388609 20	$^1\text{H}$	$\text{LiNO}_3; \text{H}_2\text{O}$
$^7\text{Li}$			$\pm 3.25636 8$	3.3		52K06	0.388637 10	$^1\text{H}$	$\text{LiCl} + \text{H}_2\text{O}$
$^7\text{Li}$			$\pm 3.25634 2$	3.3		52L18	$\pm 0.3886341 10$	$^1\text{H}$	$\text{LiNO}_3; \text{H}_2\text{O}$
$^7\text{Li}$			$+3.25636 2$	3.3		54W37	$\pm 1.469225 3$	$^{23}\text{Na}$	$\text{LiCl};$ not given
$^7\text{Li}$					$\pm 0.069^* q$	61An17			$\text{LiNO}_3$ crystal
$^7\text{Li}$			$\pm 3.25636 4$	3.3		62Ya06	$\pm 0.3886357 16$	$^1\text{H}$	$\text{LiCl} + \text{H}_2\text{O}$
$^7\text{Li}$			$\pm 3.256366 18$	3.29		65Hu13	$\pm 0.38863668 90$	$^1\text{H}$	saturated $\text{LiF}$ in $\text{H}_2\text{O}$ at 23.5, 10800G
$^7\text{Li}$			$\pm 3.25636 2$	3.3		67Lu06	$\pm 0.3886375 13$	$^1\text{H}$	$\text{LiCl} + \text{D}_2\text{O}$
$^7\text{Li}$			$\pm 3.2560328^1 6$	—		Adj.	0.38863618 8	$^1\text{H}$	Least squares adj. of $^2\text{H}$ , $^7\text{Li}$ and $^{23}\text{Na}$ ratios
$^8\text{Li}$	0.8s	[2]	$\pm 1.6532^* 8$	2		59C68	$\nu_L = 3.413 \text{ MHz}$ $H_o = 5418 \text{ 1 gauss}$		$\text{LiF}$ crystal
$^8\text{Li}$	0.8s		positive <sup>ab</sup>			62Co08			$\text{LiF}$
$^8\text{Li}$	0.8s	[2]	$\pm 1.6532^* 8$	2		67Gu14	$\nu = 2.0570 \text{ 7MHz}$ $H_o = 3264.9 \text{ 4 gauss}$		$^7\text{LiF}$
$^8\text{Li}$	0.85s	[2]	$\pm 1.65362^{app} 22,$ $\pm 1.65288^{app} 20,$ $\pm 1.65270^{app} 30$			71Ha67			$^7\text{Li(d,p)}$ recoils in Au, Pt, Pd foils

Table E: Nuclear Moments by Nuclear Magnetic Resonance — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	Diam. Cor. (nm $\times 10^4$ )	$Q$	Refer.	$\nu/\nu'$ standard	Stan-dard	Chemical Forms
$^9_4\text{Be}$			$\pm 1.17745$ 2	1.8		49D25	0.1405187 20	$^1\text{H}$	$\text{BeF}_2 + \text{H}_2\text{O}$
$^9_4\text{Be}$			negative		$\approx \pm 0.02^q$	51A11		$^1\text{H}$	$\text{Be}(\text{NO}_3)_2 + \text{H}_2\text{O}$
$^{10}_4\text{Be}$		$3/2^q$				51H50	$Q/Q^{(27)\text{Al}} \approx 0.1$	$^{27}\text{Al}$	$\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$
$^{10}_4\text{Be}$		$3/2^q$				51S17			$\text{BeAl}_2\text{O}_4$ crystal
$^{10}_4\text{Be}$			$\pm 1.17756$ 9	1.8		51S33	0.915475 70	$^2\text{H}$	$\text{BeCl}_2; \text{D}_2\text{O}$
$^{10}_4\text{Be}$		$3/2^q$			$\approx \pm 0.02^q$	53K50			Be powdered
$^{10}_4\text{Be}$		$3/2^q$	$\pm 1.1776$ 2	2		56B48	$eqQ = \pm 0.504$ 4MHz		$\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$ crystals
$^{10}_4\text{Be}$					$\pm 0.032^{cq}$	60Po09	$(eqQ = 48\text{kHz})$		(powdered Be)
$^{10}_5\text{B}$	0.77s	[2]	$\pm 1.03551^{+j}$ 25	2.1		73Mi26	$\nu = 1.90438\text{MHz}$		$^6\text{Li}(\text{He},n)^8\text{B}$ —recoils in Pt foil
							$\nu_p = 20.5493 \pm 55$ and $20.5434 \pm 100$ (for $H_o$ )		
							‡Corrected using $\sigma_p(\text{H}_2\text{O}) = 26.5\text{ppm}$		
$^{10}_5\text{B}$			$\pm 1.80105$ 18	3.6		53T01	0.700065 70	$^2\text{H}$	$\text{Na}_2\text{B}_2\text{O}_4; \text{D}_2\text{O}$
			$\pm 1.80073$ 8				1.11282 5	$^{85}\text{Rb}$	$\text{Na}_2\text{B}_2\text{O}_4; \text{RbCl}$
$^{10}_5\text{B}$			$\pm 1.80059$ 2	3.6		58B187	0.3348636 22	$^{11}\text{B}$	$\text{NaBO}_2$
$^{11}_5\text{B}$			$\pm 2.68845$ 4	5.3		49A12	0.320827 4	$^1\text{H}$	$\text{KBO}_2 + \text{K}_2\text{B}_2\text{O}_4 + \text{H}_2\text{O}$
$^{11}_5\text{B}$			$\pm 2.68875$ 13	5.3		51S33	0.825615 40	$^7\text{Li}$	$\text{Na}_2\text{B}_2\text{O}_4; \text{LiC}_2\text{H}_3\text{O}_2$
$^{11}_5\text{B}$			$\pm 2.68854$ 3	5.3		52L18	$\pm 0.3208381$ 8	$^1\text{H}$	$\text{Na}_2\text{B}_2\text{O}_4; \text{H}_2\text{O}$
$^{11}_5\text{B}$			$\pm 2.68854$ 3	5.3		65Hu13	$\pm 0.3208366$ 18	$^1\text{H}$	$\text{BF}_3 \cdot 2\text{H}_2\text{O}$ at
							$\pm 0.32083766$ 22	$^1\text{H}$	23.5, 10800G
$^{11}_5\text{B}$			$\pm 2.6880102^{+1}$ 17	—		Wtd.Ave.	0.3208377 2	$^1\text{H}$	
$^{12}_5\text{B}$	20.4ms	(1)	$+1.003^{+j}$ 1			67Su03,	1.79641 $\pm$ 32,	$^1\text{H}$	$^{11}\text{B}(\text{d},\text{p})$ recoils in Cu;
						68Su05	1.79637 $\pm$ 39;		Pt; and Au foils
							1.79510 $\pm$ 25,		
							1.79526 $\pm$ 29;		
							1.79639 $\pm$ 22		
$^{12}_5\text{B}$	20.4ms	1			$\pm 0.017^{+*2}$	70Su04	‡Corrected using $\sigma_p(\text{H}_2\text{O}) = 26.5\text{ppm}$		
						71Mi06	$eqQ = 154$ 16; 49 5kHz	$^{11}\text{B}$	powdered $\text{TiB}_2$ ;
							$Q^{12}/Q^{11} = \pm 0.42$ 4	$^{11}\text{B}$	$\text{ZrB}_2$
$^{12}_5\text{B}$	20.4ms	(1)	$+1.00285^{+kn+15}_{-14}$			70Wi17	‡Used $Q^{11} = +0.04065$ 26 (70Ne21)		
					$+0.030^{+*8}$				
$^{12}_5\text{B}$	20.4ms	(1)			$\approx \pm 0.0346^{+*p}$	71Wi28	$eqQ = 54.9$ 6kHz		$^{12}\text{B}$ recoils in Be single crystal
$^{13}_5\text{B}$	19ms	[3/2]	$\pm 3.17712^{+kn}_{-51}$			71Wi09	0.379104 25	$^1\text{H}$	$^{11}\text{B}(\text{t},\text{p})$ recoils in Pd, Au, Pt
$^{13}_5\text{B}$	19ms	[3/2]			$\approx \pm 0.08$	73Ha71	$Q^{13}/Q^{12} = 2.79$ 6 $eqQ^{13} = 130$ 2, $eqQ^{12} = 46.5$ 5kHz		$^{11}\text{B}(\text{d},\text{p})$ and $^{11}\text{B}(\text{t},\text{p})$ recoils in Mg crystal
$^{13}_6\text{C}$		1/2	$\pm 0.702388^d$ 9	1.83		54R34	0.2514431 $\pm$ 5	$^1\text{H}$	$^{13}\text{CH}_3\text{I}$
$^{13}_6\text{C}$			$\pm 0.70234$ 14	1.8		49P08	0.25143 5	$^1\text{H}$	$^{13}\text{CH}_3\text{I}$ ; oil

Table E: Nuclear Moments by Nuclear Magnetic Resonance — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	Diam. Cor. (nm $\times 10^4$ )	$Q$	Refer.	$\nu/\nu'$ standard	Standar-	Chemical Forms
$^{12}_7\text{N}$	12ms	(1)	+0.4572 <sup>a</sup> 1	1		68Su05	0.081817 <sup>‡</sup> 23; 0.081850 <sup>‡</sup> 23, 0.081869 <sup>‡</sup> 23; 0.081836 <sup>‡</sup> 13	<sup>1</sup> H <sup>1</sup> H <sup>1</sup> H <sup>1</sup> H	$^{10}\text{B}(\text{He},\text{n})$ recoils in Al; Cu; Pt
							‡Includes correction of 26.5ppm for proton resonance in $\text{H}_2\text{O}$		
$^{12}_7\text{N}$	12ms	$1\ddagger^*$				71Mi06			$^{10}\text{B}(\text{He},\text{n})$ recoils in bcc metals
$^{14}_7\text{N}$			+0.40370 4	1.31		51P02	0.47070 5	<sup>2</sup> H	$\text{HNO}_3; \text{D}_2\text{O}$
$^{14}_7\text{N}$			$\pm 0.40371$ 2	1.31		53T01	0.74837 4	<sup>85</sup> Rb	$\text{HNO}_3; \text{RbCl}$
$^{14}_7\text{N}$			+0.403603 <sup>d</sup> 7	1.31		59A134	0.072236947 <sup>d</sup> 80	<sup>1</sup> H	$\text{NH}_4\text{Cl}$
$^{14}_7\text{N}$			+0.403602 <sup>d</sup> 7	1.31		62Ba63	0.072236749 <sup>d</sup> 10	<sup>1</sup> H	$\text{NH}_4^+$
$^{14}_7\text{N}$			+0.403565 <sup>e</sup> 10			64Ball	(0.072236749 10)	<sup>1</sup> H	$\text{NH}_4^+$
$^{14}_7\text{N}$			$\pm 0.403747$ 7	1.31		68Sc03	+0.072262607 <sup>‡</sup> 13	<sup>1</sup> H	10M aqueous
						(62Ba63)	(0.072236749 10)	<sup>1</sup> H	$(\text{NH}_4)(\text{NO}_3)$
							‡Used measured ratios for: $^{14}\text{N}: \nu(\text{NO}_3)/\nu(\text{NH}_4) = 1.0003556$ 1 $^1\text{H}: \nu(\text{NH}_4)/\nu(\text{H}_2\text{O}) = 1.00000236$ 5		
							to correct to $\text{HNO}_3$ value		
$^{14}_7\text{N}$			$\pm 0.40361558$ <sup>1</sup> 6	—		68Sc03	0.07226261 1	<sup>1</sup> H	
$^{15}_7\text{N}$			-0.28305 2	0.92		50P06	0.66004 4	<sup>2</sup> H	$^{15}\text{NH}_3; \text{D}_2\text{O}$
$^{15}_7\text{N}$			-0.28317 2	0.92		51P02	1.4027 1	<sup>14</sup> N	$\text{NaNO}_3$
$^{15}_7\text{N}$			-0.283078 <sup>d</sup> 5	0.92		59A134	0.101330930 <sup>d</sup> 80	<sup>1</sup> H	$\text{NH}_4\text{Cl}$
			-0.283179 <sup>d</sup> 5				1.4027576 15	<sup>14</sup> N	$\text{NH}_4\text{Cl}$
$^{15}_7\text{N}$			$\pm 0.283179$ 5	0.92		61Br13	1.4027566 10	<sup>14</sup> N	liquid N
$^{15}_7\text{N}$			-0.283077 <sup>d</sup> 5	0.92		62Ba63	0.101330447 <sup>d</sup> 10	<sup>1</sup> H	$\text{NH}_4^+$
			-0.283179 <sup>d</sup> 5				1.40275480 <sup>d</sup> 20	<sup>14</sup> N	$\text{NH}_4^+$
$^{15}_7\text{N}$			-0.283051 <sup>e</sup> 7			64Ball	(0.101330447 10)	<sup>1</sup> H	$\text{NH}_4^+$
$^{17}_8\text{O}$	5/2		-1.89372 10	7.5		51A08	+0.88313 4	<sup>2</sup> H	$\text{H}_2^{17}\text{O} + \text{D}_2\text{O}$
$^{17}_9\text{F}$	66s	[5/2]	$\pm 4.7224^* 12$	24		66Su01	0.33797, 0.33804	<sup>1</sup> H	$^{16}\text{O}(\text{d},\text{n})\text{F}$ recoils in $\text{CaF}_2$
$^{19}_9\text{F}$			$\pm 2.62896$ 7	12.2		49S56	0.940934 15	<sup>1</sup> H	$\text{C}_2\text{F}_3\text{Cl}_3; \text{H}_2\text{O}$
$^{19}_9\text{F}$			$\pm 2.62861$ 6	12.2		50G65	0.940807 10	<sup>1</sup> H	$\text{HF} + \text{H}_2\text{O}$
$^{19}_9\text{F}$			$\pm 2.6285$ 2	12.2		51B82	0.940760 50	<sup>1</sup> H	$\text{BeF}_2 + \text{H}_2\text{O}$
$^{19}_9\text{F}$			$\pm 2.62863$ 6	12.2		51K25	0.940814 9	<sup>1</sup> H	$\text{HF} + \text{H}_2\text{O}$
$^{19}_9\text{F}$			$\pm 2.62874$ 6	12.2		52L18	0.9408545 30	<sup>1</sup> H	$\text{CHFCl}_2; \text{H}_2\text{O}$
			$\pm 2.62896$ 6	12.2			0.9409330 30	<sup>1</sup> H	$\text{CFCl}_3; \text{H}_2\text{O}$
$^{19}_9\text{F}$			+2.628383 <sup>e</sup> 5			64Ball	(0.9407714 14)	<sup>1</sup> H	HF
$^{19}_9\text{F}$			$\pm 2.62880$ 6	12.2		65Hu13	0.9408762 22 0.94087636 10	<sup>1</sup> H <sup>1</sup> H	$\text{C}_6\text{H}_5\text{CF}_3$ at 23.5, 10800G
$^{20}_9\text{F}$	11s	[2]	+2.094 <sup>a</sup> 2	10		63Ts01			$\text{CaF}_2$ crystal
$^{20}_9\text{F}$	11s	[2]	$\pm 2.0935^* 9$	10		67Gu14	$\nu = 2.1820$ 7MHz $H_o = 2735.8$ 4gauss		$\text{CaF}_2$
$^{20}_9\text{F}$	11s	[2]			$\pm 0.064^*$	73Ac03	$eqQ = 5.77$ 2MHz $Q/Q^{19}(197\text{keV}) =$ $\pm 0.108$ 4		$\text{MgF}_2$ crystal(polar.n, ); $H_o = 4.35\text{kG}$
$^{23}_{11}\text{Na}$			$\pm 2.21736$ 12	13.9		51S33	1.08883 5	<sup>45</sup> Sc	$\text{Na}_2\text{B}_2\text{O}_4; \text{ScCl}_3$
$^{23}_{11}\text{Na}$			$\pm 2.21713$ 14	13.9			1.08872 6	<sup>45</sup> Sc	$\text{NaBr}; \text{ScCl}_3$
$^{23}_{11}\text{Na}$			$\pm 2.21751$ 10	13.9		52K06	0.264514 9	<sup>1</sup> H	$\text{NaI} + \text{H}_2\text{O}$
$^{23}_{11}\text{Na}$			$\pm 2.21754$ 7	13.9		52L18	+0.2645182 7	<sup>1</sup> H	$\text{Na}_2\text{B}_2\text{O}_4; \text{H}_2\text{O}$
									$\text{NaBr}; \text{H}_2\text{O}$
$^{23}_{11}\text{Na}$			+2.21753 8	13.9		54W37	1.723167 34	<sup>2</sup> H	$\text{NaCl} + \text{D}_2\text{O}$

Table E: Nuclear Moments by Nuclear Magnetic Resonance — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	Diam. Cor. (nm x $10^4$ )	$Q$	Refer.	$\nu/\nu'$ standard	Stan-dard	Chemical Forms
$^{23}_{11}\text{Na}$ $^{23}_{11}\text{Na}$			$\pm 2.21755\ 7$ $\pm 2.2161562\ 6$	13.9 —		67Lu06 Adj.	$\pm 1.7231746\ 4$ 0.26451775 7	$^2\text{H}$ $^1\text{H}$	$\text{NaCl} + \text{D}_2\text{O}$ Least squares adj. of $^2\text{H}$ , $^7\text{Li}$ and $^{23}\text{Na}$ ratios
$^{25}_{12}\text{Mg}$			-0.85540 9	6.1		51A11	0.84714 8	$^{14}\text{N}$	$\text{MgCl}_2$ ; $\text{HNO}_3$
$^{27}_{13}\text{Al}$ $^{27}_{13}\text{Al}$ $^{27}_{13}\text{Al}$ $^{27}_{13}\text{Al}$ $^{27}_{13}\text{Al}$ $^{27}_{13}\text{Al}$ $^{27}_{13}\text{Al}$		5/2 <sup>a</sup>	$\pm 3.6412\ 4$ $\pm 3.64161\ 14$ $\pm 3.6411\ 2$ $\pm 3.64148\ 18$ $\pm 3.64135\ 14$	29 28.9 29 28.9 28.9		49B07 50G65 50P66 51S33 52K06 52L18	0.26056 3 0.985143 10 1.07261 5 0.260579 8 0.2605694 10	$^1\text{H}$ $^{23}\text{Na}$ $^{45}\text{Sc}$ $^1\text{H}$ $^1\text{H}$ $^1\text{H}$	not given $\text{NaAlO}_2$ $\text{Al}_2\text{O}_3$ crystal $\text{AlCl}_3$ ; $\text{ScCl}_3$ $\text{AlCl}_3 + \text{H}_2\text{O}$ $\text{AlCl}_3 + \text{H}_2\text{O}$ $\text{AlCl}_3$ ; $\text{H}_2\text{O}$ $\text{AlCl}_3 + \text{NaBr}$ $2(\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18})$ ( $\text{Al}_2\text{O}_3$ crystal) $\text{AlCl}_3 + \text{D}_2\text{O}$ $\text{Al}_2\text{O}_3$
$^{27}_{13}\text{Al}$ $^{27}_{13}\text{Al}$ $^{27}_{13}\text{Al}$ $^{27}_{13}\text{Al}$ $^{27}_{13}\text{Al}$		5/2 <sup>a</sup>	$+3.64128\ 15$ $\pm 3.6414\ 3$ $\pm 3.64132\ 14$	28.9 29 28.9	+0.377* <sup>cq</sup> +0.155* <sup>c‡</sup>	54W37 56B48 66Ar11 68Ep01 70Sa08	0.985055 12 56B48 66Ar11 68Ep01 70Sa08	$^{23}\text{Na}$ $^2\text{H}$	$\text{AlCl}_3 + \text{NaBr}$ $2(\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18})$ ( $\text{Al}_2\text{O}_3$ crystal) $\text{AlCl}_3 + \text{D}_2\text{O}$ $\text{Al}_2\text{O}_3$
$^{27}_{13}\text{Al}$									‡Used eq $Q$ =2.40MHz(Pound), 1-R=1.005, 1- $\gamma$ =3.59
$^{27}_{13}\text{Al}$					+0.148* <sup>c‡</sup>	70Sh16			$\text{Al}_2\text{O}_3$
$^{27}_{13}\text{Al}$			$\pm 3.6384346\ 9$	—		(68Ep01)	0.26056752 7	$^1\text{H}$	‡Used eq $Q$ =2.40MHz(Pound), 1-R=1.005, 1- $\gamma$ =3.59
$^{28}_{14}\text{Si}$	0 <sup>d</sup>					54W08	$g^{28}/g^{29} < 0.04^d$ , if $I=1$	$^{29}\text{Si}$	$^{28}\text{SiF}_4$
$^{29}_{14}\text{Si}$ $^{29}_{14}\text{Si}$ $^{29}_{14}\text{Si}$		1/2 <sup>d</sup>	-0.55526 4	4.9		53W51 54O01 54W08	1.29410 7	$^2\text{H}$	cobalt glass; $\text{D}_2\text{O}$ $\text{SiH}_4$ liquid $^{29}\text{SiF}_4$
$^{29}_{15}\text{P}$	4.2s	[1/2]	$\pm 1.2349^*\ 3$	13		71Su13	$\mu_{\text{unc}} = 1.23374\ 9$ 1.23356 3		Si on Cu(d,n) recoils in red P; Si
$^{31}_{15}\text{P}$ $^{31}_{15}\text{P}$ $^{31}_{15}\text{P}$ $^{31}_{15}\text{P}$ $^{31}_{15}\text{P}$ $^{31}_{15}\text{P}$			$\pm 1.1321\ 2$ $\pm 1.13161\ 12$ $\pm 1.13183\ 8$ $\pm 1.13159\ 6$ $+1.13161\ 6$ $+1.13160\ 6$	11 11.0 11.0 11.0 11.0 11.0		48P09 49B07 51S33 52K06 54W37	1.5310 3 0.40481 4 1.04182 5 0.404804 10 1.530366 40 1.041611 30	$^{23}\text{Na}$ $^1\text{H}$ $^7\text{Li}$ $^1\text{H}$ $^{23}\text{Na}$ $^7\text{Li}$	$\text{P}_2\text{O}_5$ ; $\text{NaI}$ not given $\text{H}_3\text{PO}_4$ ; $\text{LiC}_2\text{H}_3\text{O}_2$ $\text{P}_2\text{O}_5 + \text{H}_2\text{O}$ $\text{H}_3\text{PO}_4$ ; $\text{NaBr}$ $\text{H}_3\text{PO}_4$ ; $\text{LiCl}$
$^{31}_{15}\text{P}$ $^{31}_{15}\text{P}$			$\pm 1.13177\ 12$ $\pm 1.13176\ 6$	11.0 11.0		55F45 63Ba23	0.404868 40 0.404862808 5	$^1\text{H}$ $^1\text{H}$	$\text{H}_3\text{PO}_4$ $(\text{CH}_3\text{O})_3\text{P}$ ; $\text{H}_2\text{O}$
$^{33}_{16}\text{S}$			+0.64348 9	6.8		53W51	1.06174 13	$^{14}\text{N}$	$\text{CS}_2$ ; $\text{HNO}_3$
$^{35}_{17}\text{Cl}$ $^{35}_{17}\text{Cl}$			+0.82180 9 $\pm 0.82186\ 5$	9.4 9.4		51P02 52W08	0.63827 6 $^{50}\text{V}/^2\text{H}=$ 0.649527 70 $^{50}\text{V}/^{35}\text{Cl}=$ 1.01758 10	$^2\text{H}$ $^2\text{H}$ thru $^{50}\text{V}$	$\text{HCl}$ ; $\text{D}_2\text{O}$ $^{50}\text{VOCl}_3$ $\text{D}_2\text{O} + \text{RbCl}$
$^{35}_{17}\text{Cl}$ $^{35}_{17}\text{Cl}$			$\pm 0.82185\ 6$ $+0.82186\ 5$ $+0.82183\ 5$	9.4 9.4 9.4		53T01 54W37	1.01481 5 0.638302 8 $^{85}\text{Rb}/^{35}\text{Cl}=$ 0.985431 18 $^{85}\text{Rb}/^2\text{H}=$ 0.628985 5	$^{85}\text{Rb}$ $^2\text{H}$ $^2\text{H}$ thru $^{85}\text{Rb}$	$\text{LiCl}$ ; $\text{RbCl}$ $\text{RbCl} + \text{D}_2\text{O}$ $\text{RbCl} + \text{D}_2\text{O}$

Table E: Nuclear Moments by Nuclear Magnetic Resonance — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	Diam. Cor. (nm $\times 10^4$ )	$Q$	Refer.	$\nu/\nu'$ standard	Standard	Chemical Forms
$^{35}_{17}\text{Cl}$	0.3My		$\pm 0.821818\ 47$	9.44		70Bl08	$\pm 0.6382716\ ^E\ 3$	$^2\text{H}$	$\text{NaCl} + \text{D}_2\text{O}$
			$\pm 0.8208743\ ^14$	—		(70Bl08)	0.09797858 5	$^1\text{H}$	
			+1.28539 9	14.8		55S110	0.74873 3	$^2\text{H}$	$\text{HCl}; \text{D}_2\text{O}$
			+0.68407 7	7.8		51P02	0.83236 7	$^{35}\text{Cl}$	$\text{HCl}$
			$\pm 0.68413\ 7$	7.8		51W24	0.83243 7	$^{35}\text{Cl}$	$\text{LiCl}$
			$\pm 0.68414\ 6$	7.8		53T01	0.84477 5	$^{85}\text{Rb}$	$\text{LiCl}; \text{RbCl}$
			$\pm 0.68412\ 5$	7.8			0.832445 4	$^{35}\text{Cl}$	$\text{LiCl}$
			$\pm 0.684075\ 40$	7.85		70Bl08	$\pm 0.5312927\ ^E\ 3$	$^2\text{H}$	$\text{NaCl} + \text{D}_2\text{O}$
						70Lu03	0.83239448 8‡	$^{35}\text{Cl}$	6.00M $\text{NaCl}$ in $\text{H}_2\text{O}$
							‡3×rms error + transform uncertainty		
$^{39}_{19}\text{K}$	110ky		$\pm 0.39150\ 4$	5.2		50C65	$\pm 0.64580\ 6$	$^{14}\text{N}$	$\text{KNO}_3; \text{HNO}_3$
			+0.39140 3	5.2		54B09	not given	$^1\text{H}$	$\text{KCO}_2\text{H}; \text{H}_2\text{O}$
			$\pm 0.39155\ 4$	5.2		55B11	$\pm 0.64588\ 6$	$^{14}\text{N}$	$\text{KF}; \text{HNO}_3$
						57K07	$Q^{41}/Q^{39}=1.22^a$		$\text{KClO}_3$ crystals
			$\pm 0.39147\ 3$	5.2		68Br16	$\pm 0.0466634\ 5$	$^1\text{H}$	$\text{H}_2\text{O}+15\text{M KCOOH}$
			$\pm 0.390952\ ^16$	—		Wtd.Ave.	0.0466636 7	$^1\text{H}$	
			+0.21486 3	2.85		54B09	$\pm 0.54886\ 8$	$^{39}\text{K}$	$\text{KCO}_2\text{H}; \text{H}_2\text{O}$
			$\pm 0.214873\ 14$	2.85		67Lu02	$\pm 0.1668530\ 8\ddagger$	$^2\text{H}$	aqueous $\text{KF}; \text{D}_2\text{O}$
						71Ka30			two spectrometers
							‡Uncertainty is 3×rms error $\pm 2\text{ppm}$ field inhomogeneity $\pm 2\text{ppm}$ field uncertainty at 2 probe sites		
$^{41}_{19}\text{K}$			$\pm 0.2145879\ ^110$	—		(67Lu02) (71Ka30)	0.02561295 12	$^1\text{H}$	
$^{41}_{20}\text{Ca}$	110ky	7/2	-1.5946 1	22.6		62Br30	0.530631 3	$^2\text{H}$	$\text{Ca}(\text{NO}_3)_2$ ; not given
		7/2	-1.31721 15	18.7		53J06	0.43832 4	$^2\text{H}$	$\text{CaBr}_2 + \text{D}_2\text{O}$
$^{41}_{21}\text{Sc}$	0.59s	[7/2]	$\pm 5.43^{*\text{p}}\ 2$			72Su05	0.2772	$^1\text{H}$	$^{40}\text{Ca}(\text{d},\text{n})$ recoils in Pt foil at 4.2°K
						50H15	0.242939 3	$^1\text{H}$	$\text{SeCl}_3$ ; not given
			$\pm 4.7564\ 4$	72		50S58	0.96954 6	$^{79}\text{Br}$	$\text{SeCl}_3; \text{NaBr}$
			$\pm 4.7557\ 10$	72		51H54	0.242939 3	$^1\text{H}$	$\text{Se}(\text{NO}_3)_3$ ; not given
			$\pm 4.7564\ 4$	72		51P02	0.9183 1	$^{23}\text{Na}$	$\text{Se}(\text{NO}_3)_3; \text{NaCl}$
			$\pm 4.7557\ 6$	72		69Lu01	$\pm 1.5824534\ ^E\ 6$	$^2\text{H}$	$\text{ScCl}_3 + \text{D}_2\text{O} + \text{H}_2\text{O} + \text{HCl}$
			$\pm 4.75591\ 36$	71.7		(69Lu01)	0.24291623 10	$^1\text{H}$	
$^{47}_{22}\text{Ti}$	5/2		$\pm 4.748745\ ^12$	—					
						53J16	0.36721 6	$^2\text{H}$	$^{47}\text{TiCl}_4$ liquid; $\text{D}_2\text{O}$
			$\pm 0.78838\ 14$	12.7		65Dr03	1.20811 1	$^{39}\text{K}$	$\text{TiCl}_4; \text{HCO}_2\text{K}$
			$\pm 0.78846\ 6$	12.7		53J16	0.36731 6	$^2\text{H}$	$^{49}\text{TiCl}_4$ liquid; $\text{D}_2\text{O}$
$^{49}_{22}\text{Ti}$	7/2		-1.10402 20	17.7		65Dr03	1.20844 1	$^{39}\text{K}$	$\text{TiCl}_4; \text{HCO}_2\text{K}$
			$\pm 1.10414\ 9$	17.7					
$^{50}_{23}\text{V}$	40Jy		+3.3471 3	57		54W37	0.649518 8	$^2\text{H}$	$\text{VOCl}_3; \text{D}_2\text{O}$
			+3.3469 3	57			$\pm 1.017583\ 11$	$^{35}\text{Cl}$	$\text{VOCl}_3; \text{RbCl}$
			+3.3470 3	57			$\pm 1.032631\ 29$	$^{85}\text{Rb}$	$\text{VOCl}_3; \text{RbCl}$
			$\pm 3.34124\ ^13$	—		Wtd.Ave.	0.0997015 10	$^1\text{H}$	
$^{51}_{23}\text{V}$	40Jy		$\pm 5.1484\ 5$	88		49K24	0.99394 3	$^{23}\text{Na}$	$\text{V}_2\text{O}_5 + \text{NaCl}$
			positive			51P02			$\text{Pb}(\text{VO}_3)_2; \text{NaCl}$
$^{51}_{23}\text{V}$			$\pm 5.1448\ 5$	88		51S33	1.08156 5	$^{45}\text{Sc}$	$\text{Na}^{51}\text{VO}_3$
			$\pm 5.1480\ 5$	88		52W21	0.993855 35	$^{23}\text{Na}$	$\text{V}_2\text{O}_5; \text{SeCl}_3$
			$\pm 5.1506\ 5$	88			0.994358 26	$^{23}\text{Na}$	$\text{NaVO}_3$
			$\pm 5.15062\ 43$	87.8		64Ho20	2.638122 1	$^{50}\text{V}$	$\text{VOCl}_3; \text{NaVO}_3$
							$Q^{50}/Q^{51}=1.27^b$		liquid $\text{VOCl}_3$

Table E: Nuclear Moments by Nuclear Magnetic Resonance — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	Diam. Cor. (nm $\times 10^4$ )	$Q$	Refer.	$\nu/\nu'$ standard	Standar-	Chemical Forms
$^{51}_{23}\text{V}$					$\pm 0.0073^{*q}$	64Na05	$(1-\gamma)eqQ=752\text{kHz}$		$\text{V}_2\text{O}_5$
$^{51}_{23}\text{V}$					$\pm 0.26^{*eq}$	66Ar11	$(1-\gamma)eqQ \approx 6.4\text{MHz}$		$(\text{V}_2\text{O}_3)$
$^{51}_{23}\text{V}$					$\approx 0.04$	67Sa10	$eqQ=740\text{kHz}$		$\text{V}_2\text{O}_5$
							$eqQ \approx 3.3\text{MHz}$		$\text{NH}_4\text{VO}_3; \text{NaVO}_3;$
									$\text{Na}_3\text{VO}_4 \cdot 14; \text{Na}_4\text{V}_2\text{O}_7 \cdot 16$
$^{53}_{24}\text{Cr}$									
$^{53}_{24}\text{Cr}$			-0.47445 5	8.6		53A06	0.78226 5	$^{14}\text{N}$	$\text{Na}_2\text{CrO}_4; \text{HNO}_3$
$^{53}_{24}\text{Cr}$			-0.47440 6	8.6		53J14	0.36820 3	$^2\text{H}$	$\text{Na}_2\text{CrO}_4; \text{D}_2\text{O}$
$^{53}_{24}\text{Cr}$						54H39			$\text{Na}_2\text{CrO}_4; \text{D}_2\text{O}$
$^{53}_{24}\text{Cr}$					$\pm 0.022^{*q}$	64Ru07			$^{53}\text{Cr}_2\text{O}_3$ powder
$^{53}_{24}\text{Cr}$					$\pm 0.026^{*eq}$	66Ar11			$(\text{Cr}_2\text{O}_3)$ powder
$^{55}_{25}\text{Mn}$	5.7d		+3.059*‡ 2 or +3.0764*‡ 6	59	+0.53*‡ 7	70Ni11	0.36961 7 $Q/Q^{55}=+1.5 2$ ‡Using $\mu_{unc}^{55}=3.442$ or 3.4614, $Q^{55}=+0.35 5$	$^{55}\text{Mn}$	$(\text{Ce}, \text{La})_2\text{Mg}_3(\text{NO}_3)_{12} \cdot 24$ at 0.1°K
$^{54}_{25}\text{Mn}$	312d		$\pm 3.284^{*‡} 5$ or $\pm 3.302^{*‡} 5$	63		67Te01			$^{54}\text{Mn}$ in Fe
$^{54}_{25}\text{Mn}$	312d		+3.278*‡ 2 or +3.2959*‡ 2	63	+0.35*‡ 4	70Ni11	0.79199 6 $Q/Q^{55}=+0.99 10$ ‡Using $\mu_{unc}^{55}=3.442$ or 3.4614, $Q^{55}=+0.35 5$	$^{55}\text{Mn}$	$(\text{Ce}, \text{La})_2\text{Mg}_3(\text{NO}_3)_{12} \cdot 24$ at 0.1°K
$^{55}_{25}\text{Mn}$			+3.4682 5	66		51P02	0.9372 1	$^{23}\text{Na}$	$\text{LiMnO}_4; \text{NaCl}$
$^{55}_{25}\text{Mn}$			$\pm 3.4674 4$	66		51S33	1.02028 5	$^{45}\text{Sc}$	$\text{Ca}(\text{MnO}_4)_2; \text{ScCl}$
$^{55}_{25}\text{Mn}$			$\pm 3.4680 3$	66		69Lu06	†1.6148654‡ 4	$^2\text{H}$	$\text{KMnO}_4 + \text{D}_2\text{O}$ at 25°C
$^{55}_{25}\text{Mn}$			$\pm 3.4614353^1 8$	—		(69Lu06)	0.24789167 6	$^1\text{H}$	
$^{57}_{26}\text{Fe}$			$\pm 0.09030 13$	1.8		67Go11	$\gamma/2\pi =$ 137.4 2Hz/G		YIG, magnetically saturated
$^{57}_{26}\text{Fe}$			$\pm 0.090604 9$	1.83		70Sc11	0.9281533 9‡ ‡3×rms error + 0.4ppm field inhomogeneity	$^{73}\text{Ge}$	$\text{Fe}(\text{CO}_5); \text{GeCl}_4$
$^{57}_{27}\text{Co}$	270d		+4.722*‡ 17		+0.49‡ 9	72Ni01	1.023 3 $Q/Q^{59}=1.29 18$ ‡Used $\mu^{59}=4.616 9$ , $Q^{59}=+0.38$	$^{59}\text{Co}$	$(\text{Ce}, \text{La})_2\text{Mg}_3(\text{NO}_3)_{12} \cdot 25$ crystal
$^{58}_{27}\text{Co}$	71.3d	[2]	+4.035*‡ 8		+0.21‡ 3	72Ni01	1.59298 2 $Q/Q^{59}=0.54 3$ ‡Used $\mu^{59}=4.616 9$ , $Q^{59}=+0.38$	$^{59}\text{Co}$	$(\text{Ce}, \text{La})_2\text{Mg}_3(\text{NO}_3)_{12} \cdot 24$ crystal
$^{59}_{27}\text{Co}$			+4.6488 7	99		51P02	0.89709 9	$^{23}\text{Na}$	$\text{K}_3\text{Co}(\text{CN})_6; \text{NaCl}$
$^{59}_{27}\text{Co}$			$\pm 4.583^e 5$			57F20			several
$^{59}_{27}\text{Co}$			$\pm 4.626^k 9$	99		67Wa16	$\gamma/2\pi =$ 1.0054 <sup>k</sup> 20kHz/G		crushed intermetallic
$^{59}_{27}\text{Co}$			$\pm 4.616^k \ddagger$	99		70Sw05	$\gamma/2\pi = 1.003 \pm \text{kHz}/G$		$\text{CoSi}; \text{CoSi}_2$
									$\text{TiFe}_{1-x}\text{Co}_x$
									Measured fields using $\mu(^{39}\text{K})=0.39090$ for aqueous KI
$^{60}_{27}\text{Co}$	5.26y		+3.790*‡ 8		+0.42‡ 5	72Ni01	0.5747 2 $Q/Q^{59}=1.11 6$ ‡Used $\mu^{59}=4.616 9$ , $Q^{59}=+0.38$	$^{59}\text{Co}$	$(\text{Ce}, \text{La})_2\text{Mg}_3(\text{NO}_3)_{12} \cdot 24$ crystal
$^{61}_{28}\text{Ni}$			$\approx \pm 0.54$			62Bu08			Ni metal
$^{61}_{28}\text{Ni}$			$\pm 0.70 4$			63St08	$\gamma/2\pi =$ 0.354 20kHz/G		$^{61}\text{Ni}$ powder

Table E: Nuclear Moments by Nuclear Magnetic Resonance - Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	Diam. Cor. (nm x $10^4$ )	$Q$	Refer.	$\nu/\nu'$ standard	Stan-dard	Chemical Forms	
$^{61}_{28}\text{Ni}$			-0.74984 $\pm$ 10	16.9		64Dr02	0.658944 5	$^{17}\text{O}$	$^{17}\text{O}$ in liquid $\text{Ni}(\text{CO})_4$	
							†Includes a chemical shift correction for O in $\text{Ni}(\text{CO})_4$ of -362 ppm [62Br46]			
$^{61}_{28}\text{Ni}$			$\pm 0.75173^j 9$	16.9		65Dr03	0.91371 4	$^{35}\text{Cl}$	Ni-Al alloy; $\text{CaCl}_2$	
$^{63}_{29}\text{Cu}$			$\pm 2.2263 5$	53		48P11	1.0022 2	$^{23}\text{Na}$	CuCl powder; NaBr powder	
$^{63}_{29}\text{Cu}$			$\pm 2.2260 5$	53		49B07	0.265056 52	$^1\text{H}$	not given	
$^{63}_{29}\text{Cu}$			$\pm 2.2267 5$	53	$\pm 0.2^q 1$	49Z02	0.26515 5	$^1\text{H}$	$\text{Cu}_2\text{Cl}_2 + \text{CuCl}_2$ ; $\text{H}_2\text{O}$	
$^{63}_{29}\text{Cu}$						51B98	$Q^{63}/Q^{65} = 1.081 3$	$K_3[\text{Cu}(\text{CN})_4]$ crystal		
$^{63}_{29}\text{Cu}$			$\pm 2.2262 3$	53		51S33	1.09125 6	$^{45}\text{Sc}$	$\text{Cu}_2\text{Cl}_2$ powder; $\text{ScCl}_3$	
$^{63}_{29}\text{Cu}$			$+ 2.2259 3$	53		54W37	1.002008 16	$^{23}\text{Na}$	$\text{Cu}_2\text{Cl}_2 + \text{CuCl}_2$ ; NaBr	
$^{63}_{29}\text{Cu}$			$\pm 2.2259$	53		72Me25	$\gamma/2\pi = 1.1285\text{kHz/G}$		CuBr in KCN	
$^{65}_{29}\text{Cu}$			$\pm 2.3846 7$	57		48P11	1.0711 2	$^{63}\text{Cu}$	CuCl powder	
$^{65}_{29}\text{Cu}$			$\pm 2.3843 6$	57		49B07	0.28391 6	$^1\text{H}$	not given	
$^{65}_{29}\text{Cu}$			$\pm 2.3854 8$	57		49Z02	0.28404 8	$^1\text{H}$	$\text{Cu}_2\text{Cl}_2 + \text{CuCl}_2$ ; $\text{H}_2\text{O}$	
$^{65}_{29}\text{Cu}$			$\pm 2.3858 3$	57		51S33	1.16951 6	$^{45}\text{Sc}$	$\text{Cu}_2\text{Cl}_2$ powder; $\text{ScCl}_3$	
$^{65}_{29}\text{Cu}$			$+ 2.3846 3$	57		54W37	1.073475 10	$^{23}\text{Na}$	$\text{CuCl}_2 + \text{Cu}_2\text{Cl}_2$ ; NaBr	
$^{65}_{29}\text{Cu}$			$\pm 2.3847 \ddagger$	57		72Me25	†Using $\mu^{65}/\mu^{63} = 1.07132 2$ [54W37]			
						74Lo12	1.0712107 $\pm$ 7	$^{63}\text{Cu}$	powdered CuCl, CuI and $\text{CuRh}_2\text{Se}_4$	
							‡Average for three materials at $H_o = 12.5$ or 14.0 kG and $T = 77$ to 494°K			
$^{67}_{30}\text{Zn}$	5/2	+0.8755 $\ddagger$ 11	21.8			53W51	0.86580 1	$^{14}\text{N}$	$\text{Zn}(\text{NH}_3)_4^{++}$	
							†Includes calculated chemical shift correction of 290 ppm [64Ba11] to correct for N in $\text{NH}_3$ to N in $\text{NO}_3$			
$^{67}_{30}\text{Zn}$		$\pm 0.87524^j 11$	21.8			67Sp04	0.0625241 $\pm$ 6	$^1\text{H}$	$^{67}\text{Zn}$ vapor; mineral oil	
$^{69}_{31}\text{Ga}$		+2.0161 3	53			54W37	0.907349 20	$^{23}\text{Na}$	$\text{GaCl}_3$ ; $\text{NaCl}$	
$^{69}_{31}\text{Ga}$		$\pm 2.0161 3$	53			55R35	0.7870148 13	$^{71}\text{Ga}$	$\text{GaCl}_3$	
$^{71}_{31}\text{Ga}$		$\pm 2.5617 9$	67			48P09	1.1529 4	$^{23}\text{Na}$	$\text{GaCl}_3$ ; $\text{NaI}$	
$^{71}_{31}\text{Ga}$		$+ 2.5616 3$	67			54W37	1.152872 8	$^{23}\text{Na}$	$\text{GaCl}_3$ ; $\text{NaCl}$	
$^{71}_{31}\text{Ga}$						71Lu15	1.2706243 3 $\ddagger$	$^{69}\text{Ga}$	saturated solution of $\text{Ga}(\text{NO}_3)_3$ in $\text{H}_2\text{O}$	
							‡3×rms error + transform uncertainty			
$^{73}_{32}\text{Ge}$		-0.8792 3	24			53J16	0.35572 4	$^{35}\text{Cl}$	$\text{GeCl}_4$ ; $\text{TiCl}_4$	
							$\nu(^{35}\text{Cl} \text{ in } \text{TiCl}_4)/\nu(^{35}\text{Cl} \text{ in } \text{RbCl})$ = 1.00088 25			
$^{73}_{32}\text{Ge}$		$\pm 0.87915 15$	24.0			54A27	0.22724 2	$^2\text{H}$	$\text{GeCl}_4$ ; $\text{D}_2\text{O} + \text{MnCl}_2$	
$^{73}_{32}\text{Ge}$		$\pm 0.87919 12$	24.0			71Ka30	$\pm 0.2272486 10 \ddagger$	$^2\text{H}$	$\text{GeCl}_4$ ; $\text{D}_2\text{O}$	
						70Sc11	$\pm 1.3619664 5 \ddagger$	$^{41}\text{K}$	$\text{GeCl}_4$ ; 9M aqueous KF	
							Earlier data of [67Lu07] incorrect due to field inhomogeneities			
$^{73}_{32}\text{Ge}$		$\pm 0.8767852^l 4$	—			(71Ka30)	0.03488401 14	$^1\text{H}$	‡3×rms error + 0.4 ppm field uncertainty	
$^{73m}_{33}\text{As}$	$5.8\mu\text{s}$	[9/2]	+5.157 <sup>skn</sup> 32			69Qu03	$ g (1+K) = 1.1495$ 57		liquid metal	
									$^{71}\text{Ga}(\alpha, 2n)$ ; assumed	
$^{75}_{33}\text{As}$		3/2	+1.4392 3	41		52J05	0.17129 3	$^1\text{H}$	$\text{Na}_3\text{AsS}_4$ ; $\text{H}_2\text{O}$	
$^{75}_{33}\text{As}$			$\pm 1.4390 2$	41		53T01	1.11569 5	$^2\text{H}$	$\text{Na}_2\text{HAsO}_4$ ; $\text{D}_2\text{O}$	
$^{75}_{33}\text{As}$			$+ 1.4390 4$	41		53W51	0.64745 15	$^{23}\text{Na}$	$\text{Na}_2\text{HAsO}_4$ ; $\text{NaCl}$	

Table E: Nuclear Moments by Nuclear Magnetic Resonance — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	Diam. Cor. (nm $\times 10^4$ )	$Q$	Refer.	$\nu/\nu'$ standard	Standar- dard	Chemical Forms
$^{77}_{34}\text{Se}$			+0.53488 8	15.8		53W51	0.72193 2	$^{23}\text{Na}$	$\text{H}_2\text{SeO}_3$ ; $\text{NaCl}$
$^{77}_{34}\text{Se}$			+0.53406 8	15.8		54W37	1.242100 19	$^2\text{H}$	$\text{H}_2\text{Se}$ ; $\text{D}_2\text{O}$
$^{78m}_{35}\text{Br}$	$100\mu\text{s}$	[4]	$\pm 4.113^{+j}_{-i} 12$	127		71Br31			molten Se-Tl alloy (pulsed p,n); $H_o=6.5\text{G}$
$^{79}_{35}\text{Br}$			$\pm 2.1056 9$	65		47P16	0.9278 3	$^{81}\text{Br}$	$\text{LiBr}$ or $\text{NaBr}$
$^{79}_{35}\text{Br}$					$\approx 0.4^b$	48P09	$Q^{79}/Q^{81}=1.75^b$	$^{127}\text{I}$	$\text{LiBr}$ ; $\text{NaI}$
$^{79}_{35}\text{Br}$			$\pm 2.1059 5$	65		49Z02	0.25059 5	$^1\text{H}$	$\text{NaBr}$ ; $\text{H}_2\text{O}$
$^{79}_{35}\text{Br}$			$\pm 2.1057 3$	65		51S33	1.03145 5	$^{45}\text{Sc}$	$\text{NaBr}$ ; $\text{ScCl}_3$
$^{79}_{35}\text{Br}$			$+2.1055 3$	65		54W37	0.947140 9	$^{23}\text{Na}$	$\text{NaBr}$
$^{79}_{35}\text{Br}$			$\pm 2.1055 3$	65		70Bl08	$1.632111^E 3\ddagger$	$^2\text{H}$	$\text{KBr}+\text{D}_2\text{O}$
$^{81}_{35}\text{Br}$							$\ddagger 3\times-\text{rms error} + \text{systematic errors}$		
$^{81}_{35}\text{Br}$			$\pm 2.2695 8$	70		47P16	1.0209 3	$^{23}\text{Na}$	$\text{LiBr}$ ; not given $\text{NaBr}$
$^{81}_{35}\text{Br}$			$\pm 2.2693 8$	70		49B07	0.27003 8	$^1\text{H}$	not given
$^{81}_{35}\text{Br}$			$\pm 2.2702 6$	70		49Z02	0.27014 5	$^1\text{H}$	$\text{NaBr}$ ; $\text{H}_2\text{O}$
$^{81}_{35}\text{Br}$			$\pm 2.2694 4$	70		51S33	1.11165 6	$^{45}\text{Sc}$	$\text{NaBr}$ ; $\text{ScCl}_3$
$^{81}_{35}\text{Br}$			$+2.2696 4$	70		54W37	1.020965 14	$^{23}\text{Na}$	$\text{NaBr}$
$^{81}_{35}\text{Br}$			$\pm 2.2696 4$	70		70Bl08	$1.759309^E 3\ddagger$	$^2\text{H}$	$\text{KBr}+\text{D}_2\text{O}$
$^{81}_{35}\text{Br}$							$\ddagger 3\times-\text{rms error} + \text{systematic errors}$		
$^{81}_{35}\text{Br}$						70Lu02	1.0779355 3 $\ddagger$	$^{79}\text{Br}$	$7.31\text{M } \text{NH}_4\text{Br}$ in $\text{H}_2\text{O}$ ; $H_o \approx 18.07\text{kG}$
$^{81m}_{35}\text{Br}$	$35\mu\text{s}$	[9/2]	$\pm 5.86^{+j}_{-i} 7$	180		71Br31			molten Se-Tl alloy (pulsed p,n); $H_o=10.4\text{G}$
$^{83}_{36}\text{Kr}$			$\pm 0.97017 16$	31.1		54B03	not given		Kr gas
$^{83}_{36}\text{Kr}$							$\ddagger$ Atomic spectra and beams measurements determine $\mu$ to be negative		
$^{83}_{36}\text{Kr}$			$\pm 0.97034 16$	31.1		68Br16	$0.8246789^E 24$	$^{39}\text{K}$	Kr gas; $\text{KCOOH}$
$^{85}_{37}\text{Rb}$			$\pm 0.97033 16$	31.1			$^{39}\text{K}/^1\text{H}=0.0466634 5$		
$^{85}_{37}\text{Rb}$			$\pm 1.3527 2$	45		51Y03	$\ddagger 0.09655207 30$	$^1\text{H}$	$\text{RbCl}$ ; $\text{H}_2\text{O}$
$^{85}_{37}\text{Rb}$			$\pm 1.3528 2$	45		52W08	$^{50}\text{V}/^2\text{H}=$	$^2\text{H}$	$\text{VOCl}_3$ ; $\text{RbCl}+\text{D}_2\text{O}$
$^{85}_{37}\text{Rb}$							$0.649527 70$		
$^{85}_{37}\text{Rb}$							$^{50}\text{V}/^{85}\text{Rb}=$		
$^{85}_{37}\text{Rb}$			$+1.3527 2$	45		54W37	$1.03262 10$		
$^{85}_{37}\text{Rb}$			$\pm 1.3527 2$	45		61Bl08	$\ddagger 0.6289789 4$	$^2\text{H}$	$\text{RbCl}$ ; $\text{D}_2\text{O}$
$^{85}_{37}\text{Rb}$			$\pm 1.3482052^1 8$	—		Wtd. Ave.	$0.096552095 54$	$^1\text{H}$	
$^{87}_{37}\text{Rb}$	$47\text{Gy}$		$\pm 2.7503 7$	92		49B07	0.32718 6	$^1\text{H}$	not given
$^{87}_{37}\text{Rb}$	$47\text{Gy}$		$\pm 2.7503 14$	92		49Z02	0.32718 16	$^1\text{H}$	$\text{Rb}_2\text{CO}_3$ ; $\text{H}_2\text{O}$
$^{87}_{37}\text{Rb}$	$47\text{Gy}$		$\pm 2.7506 5$	92		51A31	$3.388966 47$	$^{85}\text{Rb}$	$\text{RbCl}$
$^{87}_{37}\text{Rb}$	$47\text{Gy}$		$\pm 2.7495 5$	92		51S33	1.25529 6	$^{27}\text{Al}$	$\text{Rb}_2\text{CO}_3$ ; $\text{AlCl}_3$
$^{87}_{37}\text{Rb}$	$47\text{Gy}$		$\pm 2.7506 5$	92		51Y03	0.32721338 55	$^1\text{H}$	$\text{RbCl}$ ; $\text{H}_2\text{O}$
$^{87}_{37}\text{Rb}$	$47\text{Gy}$		$+2.7506 5$	92		54W37	1.237041 8	$^{23}\text{Na}$	$\text{RbCl}$ ; $\text{NaCl}$
$^{87}_{37}\text{Rb}$	$47\text{Gy}$		$\pm 2.7507 5$	92		61Bl08	2.1315984 2	$^2\text{H}$	$\text{RbCl}$ ; $\text{D}_2\text{O}$
$^{87}_{37}\text{Rb}$	$47\text{Gy}$		$\pm 2.7505 5$	92		67Lu06	$2.1315419^E 15$	$^2\text{H}$	$\text{RbCl}+\text{D}_2\text{O}$
$^{87}_{38}\text{Sr}$			$-1.0930 2$	38		53J14	0.28232 3	$^2\text{H}$	$^{87}\text{SrBr}_2$ ; $\text{D}_2\text{O}$
$^{89}_{39}\text{Y}$			$-0.13732 3$	4.9		54B09	0.048994 1	$^1\text{H}$	$\text{Y}(\text{NO}_3)_3$ ; $\text{H}_2\text{O}$
$^{89}_{39}\text{Y}$			$\pm 0.137344 26$	4.91		65Ba42	0.678141 18	$^{14}\text{N}$	$\text{YCl}_3$ ; $\text{HNO}_3$

Table E: Nuclear Moments by Nuclear Magnetic Resonance — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	Diam. Cor. (nm $\times 10^4$ )	$Q$	Refer.	$\nu/\nu'$ standard	Stan- dard	Chemical Forms
$^{91}_{40}\text{Zr}$		5/2	-1.3028 2	48		57Br26	0.60557 <i>I</i>	$^2\text{H}$	$(\text{NH}_4)_2\text{ZrF}_6 + \text{D}_2\text{O}$
$^{93}_{41}\text{Nb}$			$\pm 6.1672$ 12	236		51S33	1.00613 5	$^{45}\text{Sc}$	$\text{Nb}_2\text{O}_5$ ; $\text{SeCl}_3$
$^{95}_{42}\text{Mo}$			-0.9136 2	36		51P02	0.97943 10	$^{97}\text{Mo}$	$\text{K}_2\text{MoO}_4$
$^{95}_{42}\text{Mo}$			-0.9328 2	37	$\pm 0.12^t$ 3	66Na04	0.9208 <i>I</i>	$^{14}\text{N}$	Mo metal
$^{97}_{42}\text{Mo}$						51P02	$ Q^{97}/Q^{95}  > 1^t$		$\text{K}_2\text{MoO}_4$ ; $\text{HNO}_3$
$^{97}_{42}\text{Mo}$						65Ka03	$Q^{97}/Q^{95} = 9.2^b$ 8		$\text{K}_2\text{MoO}_4$ solution
$^{97}_{42}\text{Mo}$						66Na04	$(Q^{97}/Q^{95}) = 9.2^b$ 8)		
$^{96}_{43}\text{Tc}$	4.3d	(6‡)	$\pm 4.60^{\pm \text{an}}$ 14			71Fo24			Tc—Fe; $H_{\text{int}} = -298$ 10kG
									‡Obtained $g$ from slope of $\nu$ vs $H$ ; spin measured by ABMR (1974)
$^{99}_{43}\text{Tc}$	210ky		+5.6807 12	234		52W02	1.46628 10	$^2\text{H}$	$\text{NH}_4\text{TcO}_4 + \text{D}_2\text{O}$
$^{103}_{45}\text{Rh}$			-0.088321 <sup>k</sup> 19	3.87		55S110	0.205574 7	$^2\text{H}$	Rh metal; $\text{D}_2\text{O}$
$^{103}_{45}\text{Rh}$			-0.08825 <sup>k</sup> 2	3.9		65Se11	not given		$\text{RhSn}_2$
$^{105}_{46}\text{Pd}$			$\pm 0.6015^j$ 6	26		62Go25	0.04388 4	$^1\text{H}$	Pd metal (finely divided); $\text{H}_2\text{O}$
$^{105}_{46}\text{Pd}$			-0.642 <sup>k</sup> 3	30		64Se13	not given		Pd metal
$^{107}_{47}\text{Ag}$			-0.11354 3	5.3		54B09	0.040468 <i>I</i>	$^1\text{H}$	$\text{AgNO}_3$ ; $\text{H}_2\text{O}$
$^{107}_{47}\text{Ag}$			-0.11358 3	5.3		54S105	0.86985 <i>I</i>	$^{109}\text{Ag}$	$\text{AgNO}_3$
$^{109}_{47}\text{Ag}$			-0.13053 3	6.1		54B09	0.046523 <i>I</i>	$^1\text{H}$	$\text{AgNO}_3$ ; $\text{H}_2\text{O}$
$^{109}_{47}\text{Ag}$			-0.13057 3	6.1		54S105	0.30316 3	$^2\text{H}$	$\text{AgNO}_3$ ; $\text{D}_2\text{O}$
$^{109}_{47}\text{Ag}$			$\pm 0.13124^j$ 3	6.1		67Na13	0.304715 6	$^2\text{H}$	$\text{Au}_x\text{Ag}_{1-x}$ ; $\text{D}_2\text{O}$
							$\gamma/2\pi = 0.199150$ 4 kHz/G		
$^{110}_{47}\text{Ag}$	24.4s		$\pm 2.7210^*$ 8	126		69Ac02	$\gamma/2\pi = 2.0645$ 6kHz/G		$\text{AgF}, \text{AgCl}, \text{AgBr}$ , $\text{Ag}_2\text{O}, \text{Ag}_2\text{O}_2$ (polar. n.); $T \sim 8^\circ\text{K}$
$^{107}_{48}\text{Cd}$	6.7h		$\pm 0.61444^i$ 15	29.4		66Mc17	0.0437924 <sup>i</sup> 20	$^1\text{H}$	Cd vapor; mineral oil
$^{109}_{48}\text{Cd}$	470d		$\pm 0.82701^i$ 20	39.5		66Mc17	0.0589435 <sup>i</sup> 20	$^1\text{H}$	Cd vapor; mineral oil
$^{111}_{48}\text{Cd}$		1/2	-0.59499 16	28.4		50P51	0.8016 <i>I</i>	$^{23}\text{Na}$	$\text{CdCl}_2$ ; $\text{NaCl}$
$^{111}_{48}\text{Cd}$			$\pm 0.59429^i$ 14	28.4		66Le21	1.1879850 <sup>i</sup> 5	$^{199}\text{Hg}$	$^{111}\text{Cd} + ^{199}\text{Hg}$ vapor
							‡Based on $\nu(^{199}\text{Hg})/\nu(^1\text{H})$ from optical pumping measurements		
$^{111}_{48}\text{Cd}$			$\pm 0.59428^i$ 14	28.4		66Mc16	0.211782 <sup>i</sup> 2	$^1\text{H}$	Cd vapor; mineral oil
$^{113}_{48}\text{Cd}$	>3Jy		-0.62245 17	29.7		50P51	0.8386 <i>I</i>	$^{23}\text{Na}$	$\text{CdCl}_2$ ; $\text{NaCl}$
$^{113}_{48}\text{Cd}$	>3Jy					59K39	1.046083 <sup>d</sup> 3	$^{111}\text{Cd}$	$\text{Cd}(\text{CH}_3)_2$
$^{113}_{48}\text{Cd}$	>3Jy		$\pm 0.62167^i$ 15	29.7		67Le22	1.0460840 <sup>i</sup> 2	$^{111}\text{Cd}$	$^{111}\text{Cd} + ^{113}\text{Cd}$ vapor
							‡Based on $\nu(^{199}\text{Hg})/\nu(^1\text{H})$ from optical pumping measurements		
$^{113}_{48}\text{Cd}$	>3Jy		$\pm 0.62167^i$ 15	29.7		66Mc16	0.221543 <sup>i</sup> 2	$^1\text{H}$	Cd vapor; mineral oil
$^{113}_{49}\text{In}$			$\pm 5.5232$ 15	271		51P02	0.82667 8	$^{23}\text{Na}$	$\text{In}(\text{NO}_3)_3$ ; $\text{NaCl}$
$^{113}_{49}\text{In}$			$\pm 5.5223$ 15	271		53T01	0.99787 4	$^{115}\text{In}$	$\text{In}(\text{NO}_3)_3$
$^{113}_{49}\text{In}$			$\pm 5.5229$ 16	271		57R42	0.9978609 12	$^{115}\text{In}$	$\text{In}(\text{ClO}_4)_3$
$^{113}_{49}\text{In}$			$\pm 5.5229$ 14	271		71Lu15	0.9978610 3‡	$^{115}\text{In}$	1.6m% $\text{In}(\text{ClO}_4)_3$ + 0.5m% $\text{H}(\text{ClO}_4)_2$ + 97.9m% $\text{H}_2\text{O}$ ; $H_o = 18.07\text{kG}$
							‡3×rms error + Fourier Transform error		

Table E: Nuclear Moments by Nuclear Magnetic Resonance — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	Diam. Cor. (nm $\times 10^4$ )	$Q$	Refer.	$\nu/\mu'$ standard	Standard	Chemical Forms
$^{115}_{49}\text{In}$	600Ty		$\pm 5.5348\ 15$	272		51P02	0.82841 8	$^{23}\text{Na}$	$\text{In}(\text{NO}_3)_3$ ; $\text{NaCl}$
$^{115}_{49}\text{In}$	600Ty		$\pm 5.5336\ 15$	272		53T01	0.901877 50	$^{45}\text{Sc}$	$\text{In}(\text{NO}_3)_3$ ; $\text{SeCl}_3$
$^{115}_{49}\text{In}$	600Ty		$\pm 5.5348\ 14$	272		60Fl03	0.219128 8	$^1\text{H}$	$\text{In}_2(\text{SO}_4)_3$ ; glycerin
$^{115}_{49}\text{In}$	600Ty		observed ultrasonically-induced			66Ma55			InAs crystal
$^{116}_{49}\text{In}$	14s		$\Delta m = \pm 3$ transitions due to hexadecapole moment						
			$\pm 2.7859^{\pm} 12$	137	$\pm 0.09^{\pm} 2$	71Wi12	$\gamma/2\pi = 2.1132$ 8kHz/G		$\text{InP}(\text{polar. th n, })$ $T = 77^\circ\text{K}$
									†From temperature dependence of $\tau_{\text{relax}}$ : used $Q^{115} = +0.83$ b
$^{115}_{50}\text{Sn}$		1/2	-0.9178 2	46		50P51	1.2362 1	$^{23}\text{Na}$	$\text{SnCl}_2$ ; $\text{NaCl}$
$^{115m}_{50}\text{Sn}$	159μs		$\pm 1.368^{\pm} 4$	69		71Br03	$\gamma/2\pi = 0.1887,$ 0.1880, 0.1893 kHz/G		liquid In metal (pulsed p,n)
$^{115m}_{50}\text{Sn}$	159μs				$\pm 0.8^{\pm} 3$	72Ri13			liquid In metal (pulsed p,n)
$^{117}_{50}\text{Sn}$		1/2	-0.9999 3	50		50P51	1.3468 1	$^{23}\text{Na}$	$\text{SnCl}_2$ ; $\text{NaCl}$
$^{119}_{50}\text{Sn}$		1/2	-1.0461 3	53		50P51	1.4090 1	$^{23}\text{Na}$	$\text{SnCl}_2$ ; $\text{NaCl}$
$^{121}_{51}\text{Sb}$			$\pm 3.3589\ 9$	174		50C57	0.90469 4	$^{23}\text{Na}$	$\text{HSbCl}_6$ ; solid $\text{NaCl}$
$^{121}_{51}\text{Sb}$			+3.3593 9	174		51P02	0.90480 9	$^{23}\text{Na}$	$\text{NaSbF}_6$ ; $\text{NaCl}$
$^{121}_{51}\text{Sb}$						58E03	1.84661 1	$^{123}\text{Sb}$	$\text{KSbF}_6$
$^{123}_{51}\text{Sb}$			$\pm 2.5465\ 7$	132		50C57	0.8442 1	$^2\text{H}$	$\text{HSbCl}_6$ ; $\text{D}_2\text{O}$
$^{123}_{51}\text{Sb}$			+2.5466 7	132		51P02	0.84423 8	$^2\text{H}$	$\text{NaSbF}_6$ ; $\text{D}_2\text{O}$
$^{125}_{51}\text{Sb}$	2.7y	7/2 $\ddagger$	$\pm 2.63\ 6$	136		68Ba70	$\gamma/2\pi = 0.570$ 14kHz/G		$^{125}\text{Sb}$ —Fe at $0.015^\circ\text{K}$
									†Spin determined by $\mu(68\text{Sb16})$ and $g(68\text{Ba70})$
$^{123}_{52}\text{Te}$	>50Ty		-0.7359 2	39		53W51	0.99085 3	$^{23}\text{Na}$	$\text{TeO}_2$ ; $\text{NaCl}$
$^{125}_{52}\text{Te}$			-0.8872 2	47		53W51	1.19457 4	$^{23}\text{Na}$	$\text{TeO}_2$ ; $\text{NaCl}$
$^{127}_{53}\text{I}$			$\pm 2.8100\ 11$	153		48P09	$\dagger 0.75664\ 20$	$^{23}\text{Na}$	solid $\text{NaI}$
$^{127}_{53}\text{I}$			$\pm 2.8084\ 13$	153		49Z02	0.20003 8	$^1\text{H}$	$\text{KI}$ ; $\text{H}_2\text{O}$
$^{127}_{53}\text{I}$			$\pm 2.8086\ 8$	153		51S33	$\dagger 1.30317\ 6$	$^2\text{H}$	$\text{KI} + \text{H}_2\text{O}$ ; $\text{D}_2\text{O} +$ $\text{H}_2\text{O} + \text{NiCl}_2$
$^{127}_{53}\text{I}$			$\pm 2.8091\ 9$	153		51W12	$\dagger 1.30337\ 20$	$^2\text{H}$	$\text{NaI} + (\text{NH}_2)_2 + \text{D}_2\text{O}$
$^{127}_{53}\text{I}$			$\pm 2.8093\ 8$	153		51Y03	$\dagger 0.200095\ 6$	$^1\text{H}$	$\text{KI}$ ; $\text{H}_2\text{O}$
$^{127}_{53}\text{I}$			$\pm 2.79382^{\pm} 18$	—		Wtd. Ave.	0.200080 14	$^1\text{H}$	
$^{129}_{53}\text{I}$	16My		+2.6173 8	143		51W12	0.86744 10	$^2\text{H}$	$\text{NaI} + (\text{NH}_2)_2 + \text{D}_2\text{O}$
$^{129}_{54}\text{Xe}$			-0.77681 23	43.4		51P02	1.0457 1	$^{23}\text{Na}$	Xe gas; $\text{NaCl}$
$^{129}_{54}\text{Xe}$			-0.77689 22	43.4		54B03	0.276633 5	$^1\text{H}$	Xe gas; $\text{H}_2\text{O}$
$^{129}_{54}\text{Xe}$			-0.77682 22	43.4		68Br12	1.80192 <sup>E</sup> 2	$^2\text{H}$	Xe gas; $\text{D}_2\text{O}$
$^{131}_{54}\text{Xe}$			+0.69066 19	38.6		54B03	0.081976 1	$^1\text{H}$	Xe gas; $\text{H}_2\text{O}$
$^{131}_{54}\text{Xe}$			+0.69083 19	38.6		68Br12	0.534155 <sup>E</sup> 3	$^2\text{H}$	Xe gas; $\text{D}_2\text{O}$
$^{133}_{55}\text{Cs}$			$\pm 2.5784\ 11$	148		49B07	0.33743 10	$^7\text{Li}$	not given
$^{133}_{55}\text{Cs}$			$\pm 2.5790\ 8$	148		51S33	0.85449 4	$^2\text{H}$	$\text{CsCl}$ ; $\text{D}_2\text{O}$
$^{133}_{55}\text{Cs}$			+2.5790 7	148		54W37	0.854496 18	$^2\text{H}$	$\text{CsNO}_3 + \text{D}_2\text{O}$
$^{133}_{55}\text{Cs}$					$\pm <0.004^t$	58B158		$^2\text{H}$	$\text{CsI}$ ; $\text{CsBr}$
$^{133}_{55}\text{Cs}$			$\pm 2.5789\ 7$	148		67Lu06	0.8544377 <sup>E</sup> 5	$^2\text{H}$	$\text{CsNO}_3 + \text{D}_2\text{O}$

Table E: Nuclear Moments by Nuclear Magnetic Resonance — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	Diam. Cor. (nm $\times 10^4$ )	$Q$	Refer.	$\nu/\nu'$ standard	Standar-	Chemical Forms
$^{133}_{55}\text{Cs}$					$\pm 3.5$ 10mb	68Ha43			$\text{Cs}_2\text{CuCl}_4$ ; $\text{Cs}_2\text{CoCl}_4$ single crystals at room $T$ ; used $1-\gamma_\infty=120.30$ aqueous CsI at 297°K
$^{133}_{55}\text{Cs}$					$\pm 2.3$ <sup>Efp</sup> 3 mb	70Or08			
$^{135}_{56}\text{Ba}$ $^{137}_{56}\text{Ba}$			$\pm 0.83717$ 25 $\pm 0.93653$ 27	49.1 54.9	56W20 56W20	1.01387 2 1.13420 5	$^{35}\text{Cl}$ $^{35}\text{Cl}$	$^{135}\text{BaCl}_2$ $^{137}\text{BaCl}_2$	
$^{138}_{57}\text{La}$	0.1Ty	5	$+3.7073$ 12	223	$\approx \pm 1^\dagger$	55S31	$0.93407$ 3 $Q^{138}/Q^{139} \approx \pm 3.5.5$	$^{139}\text{La}$	not given
$^{139}_{57}\text{La}$ $^{139}_{57}\text{La}$			$\pm 2.7780$ 9 $\pm 2.7783$ 9	167 167	49D13 51S33	0.141251 14 0.92025 6	$^1\text{H}$ $^2\text{H}$	$\text{LaCl}_3 + \text{H}_2\text{O}$ $\text{LaCl}_3$ ; $\text{D}_2\text{O}$	
$^{153}_{63}\text{Eu}$						64Ch26	0.4438	$^{151}\text{Eu}$	EuS powder at 4.2°K
$^{155}_{64}\text{Gd}$ $^{155}_{64}\text{Gd}$						64Bo09 65Bu14	0.753 5 0.763	$^{157}\text{Gd}$ $^{157}\text{Gd}$	GdN GdAl <sub>2</sub>
$^{163}_{66}\text{Dy}$						66Ko14	$1.40 \pm 1$ $Q^{163}/Q^{161} = 1.06 \pm 1$	$^{161}\text{Dy}$	powdered Dy-metal in ferromagnetic state
									<sup>‡</sup> Used spin-echo technique
$^{171}_{70}\text{Yb}$			$+0.4930$ 5	40		64Go06	1.7874 15	$^{35}\text{Cl}$	$\text{YbCl}_2$ ; $\text{NaCl}$ $\text{YbS}$ ; $\text{NaCl}$
$^{173}_{70}\text{Yb}$			$\pm 0.6791$ 6	54		64Go06	(0.275497 <sup>i</sup> 12)	$^{171}\text{Yb}$	
$^{175}_{71}\text{Lu}$			$\pm 2.229$ 1 $\pm 2.231$ 1	180 180		62Re02	0.73677 2 0.73732 2	$^2\text{H}$ $^2\text{H}$	$\text{LuB}_{12}$ $\text{LuSb}$
$^{181}_{73}\text{Ta}$			$\pm 2.360 \pm 2$	200		60Be23	not given		$\text{KTaO}_3$
									<sup>‡</sup> Determined magnetic field using $^7\text{Li}$ resonance
$^{183}_{74}\text{W}$ $^{183}_{74}\text{W}$			$+0.1167 \pm 10$ $\pm 0.11722$ 5	10 10.1		55S110 61Kl01	0.27395 3 not given	$^2\text{H}$	W powder; $\text{D}_2\text{O}$ $\text{WF}_6$
$^{185}_{75}\text{Re}$ $^{187}_{75}\text{Re}$ $^{187}_{75}\text{Re}$ $^{187}_{75}\text{Re}$	60Gy		$+3.1718$ 14 $+3.2044$ 14	281 284	large <sup>b</sup> large <sup>b</sup>	51A11 51A11 68Na12 70Be75	0.85114 9 0.85987 9 1.01007 5 1.01008 8	$^{23}\text{Na}$ $^{23}\text{Na}$ $^{187}\text{Re}$ $^{187}\text{Re}$	$\text{NaReO}_4$ ; $\text{NaCl}$ $\text{NaReO}_4$ ; $\text{NaCl}$ $\text{ReO}_3$ metal $\text{Be}_{22}\text{Re}$ at 300°K
$^{187}_{76}\text{Os}$			$\pm 0.06432$ 3	5.8		68Sc06	0.8910814 3 0.8910825 <sup>‡</sup> 5	$^{41}\text{K}$ $^{41}\text{K}$	molten $\text{OsO}_4$ ; aqueous KF
									<sup>‡</sup> Corrected for susceptibilities of $\text{OsO}_4 (-0.211 \times 10^{-6})$ and $\text{KF} (-0.83 \times 10^{-6})$
$^{189}_{76}\text{Os}$	3/2		$+0.65655 \pm 30$	59		54L36	0.791896 93	$^{35}\text{Cl}$	molten $\text{OsO}_4$ ; $\text{TiCl}_4$
									<sup>‡</sup> Used $\nu(^{35}\text{Cl in TiCl}_4)/\nu(^{35}\text{Cl in RbCl}) = 1.00088$ 25 of 53J16
$^{189}_{76}\text{Os}$			$\pm 0.65652$ 30	59		68Sc03	1.074639 5	$^{14}\text{N}$ in $\text{NO}_3^-$	molten $\text{OsO}_4$ ; $\text{NH}_4(\text{NO}_3)$ solution (cylindrical samples)

Table E: Nuclear Moments by Nuclear Magnetic Resonance — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	Diam. Cor. (nm $\times 10^4$ )	$Q$	Refer.	$\nu/\nu'$ standard	Standar-	Chemical Forms
$^{191}\text{Ir}$			+0.1453 <sup>k</sup> 6	13.5		68Na01	$\nu/H(\text{in kHz/G})$ =0.074133 18		Ir metal; used $K=+0.013$ 4
$^{191\text{m}}\text{Ir}$	4.9s	[11/2]	$\pm 6.08^*\ 36$	560		71Es03	$\nu=389.690\pm 13;$ 1174.85 $\pm 12\text{MHz}$	0.08% $^{191}\text{Os}$ in Ni, $H_{\text{int}}$ =-467 3kG; 0.04% $^{191}\text{Os}$ in Fe, $H_{\text{int}}$ =-1405 8kG	
$^{192}\text{Ir}$	74d		$\pm 1.901^*\ 11$	174		71Es03	$\ddagger$ Extrapolated to $H_o=0$ $\nu=167.661\pm 35;$ 504.192 $\pm 50\text{MHz}$	0.03% Ir in Ni, $H_{\text{int}}$ =-467 3kG; 0.03% Ir in Fe, $H_{\text{int}}$ =-1405 8kG	
$^{193}\text{Ir}$			+0.1583 <sup>k</sup> 6	14.7		68Na01	$\ddagger$ Extrapolated to $H_o=0$ $\nu/H(\text{in kHz/G})$ =0.080732 6	Ir metal; used $K=+0.013$ 4	
							$\ddagger$ Used $\nu(^{109}\text{Ag})/H=0.199150\text{kHz/G}$ for Ag-metals		
$^{195}\text{Pt}$		1/2	+0.6060 3	57		51P02	0.81273 8	$^{23}\text{Na}$	$\text{H}_2\text{PtCl}_6$ ; NaCl
$^{195\text{m}}\text{Pt}$			$\pm 0.6060\pm 3$	57		63Dr05	0.812667 4	$^{23}\text{Na}$	$\text{H}_2\text{PtCl}_6$
$^{195\text{m}}\text{Pt}$			$\pm 0.6022\pm 3$	57		68Ze04 (63Dr05)	$\ddagger$ Not corrected for chemical shift which may be as large as +0.7%		$\text{H}_2\text{PtI}_6+\text{H}_2\text{O}$ ; least paramagnetic compound tested
							$\ddagger$ Chemical shift with respect to $\text{H}_2\text{PtCl}_6$ is -0.63%		
$^{195\text{m}}\text{Pt}$	4.1d	[13/2]	$\pm 0.602^*\pm 15$	56		72Ba22	$\nu=89.5\ 5\text{MHz}$		Pt-Fe, $^{60}\text{Co}$ ; $H_{\text{hf}}=$ -1280 26kG
							$\ddagger$ Uncorrected for possible hyperfine anomaly		
$^{197}\text{Au}$			+0.14726 <sup>j</sup> 7	14.0		67Na13	$\nu/H(\text{in kHz/G})$ =0.074125 4		$\text{Au}_x\text{Ag}_{1-x}$
$^{200\text{m}}\text{Au}$	18.7h	[12]	$\pm 6.10^*\pm 10$	600		73Ba83	$\ddagger$ 2.5% hyperfine anomaly included		
$^{183}\text{Hg}$	8.8s	1/2	+0.518 <sup>*</sup> 9	50		72Bo09			Also measured by optical pumping
$^{185}\text{Hg}$	50s	1/2	+0.504 <sup>*</sup> 4	49		72Bo09			Also measured by optical pumping
$^{199}\text{Hg}$		1/2	+0.50416 24	48.6		51P02	$\ddagger 1.1647\ 1$	$^2\text{H}$	$\text{Hg}_2(\text{NO}_3)_2$ ; $\text{D}_2\text{O}$
$^{199}\text{Hg}$			+0.50272 <sup>j</sup> 24	48.6		61Ca21	$\ddagger 0.1782706^j\ 3$	$^1\text{H}$	Hg gas; $\text{H}_2\text{O}$
$^{199}\text{Hg}$			$\pm 0.49930^j\ 4$	—	(51P02)	0.178788 15	$^1\text{H}$	NMR-value	
$^{201}\text{Hg}$			$\pm 0.4978563^j\ 8$	—	(61Ca21)	0.1782706 3	$^1\text{H}$	OP-value	
$^{201}\text{Hg}$			-0.55671 <sup>j</sup> 27	53.7	61Ca21	0.0658066 <sup>j</sup> 3	$^1\text{H}$	Hg gas; $\text{H}_2\text{O}$	
$^{203}\text{Tl}$			$\pm 1.6118\ 8$	158		49P08	0.571499 50	$^1\text{H}$	$\text{TlC}_2\text{H}_3\text{O}_2$ ; $\text{H}_2\text{O}$
$^{203}\text{Tl}$		1/2	+1.6116 8	158		50P51	0.5714 1	$^1\text{H}$	$\text{TlC}_2\text{H}_3\text{O}_2+\text{H}_2\text{O}$
$^{203}\text{Tl}$			$\pm 1.6116\ 8$	158		51S33	0.99026 5	$^{205}\text{Tl}$	$\text{TlC}_2\text{H}_3\text{O}_2$
$^{203}\text{Tl}$			$\pm 1.6115\ 8$	158		63Ba23	0.57139145 4	$^1\text{H}$	$\text{TlC}_2\text{H}_3\text{O}_2$ ; $\text{H}_2\text{O}$
$^{205}\text{Tl}$			$\pm 1.6277\ 8$	160		49P08	0.577135 50	$^1\text{H}$	$\text{TlC}_2\text{H}_3\text{O}_2$ ; $\text{H}_2\text{O}$
$^{205}\text{Tl}$		1/2	+1.6274 8	160		50P51	0.5770 1	$^1\text{H}$	$\text{TlC}_2\text{H}_3\text{O}_2+\text{H}_2\text{O}$
$^{205}\text{Tl}$			$\pm 1.6274\ 8$	160		51S33	0.57702 3	$^1\text{H}$	$\text{TlC}_2\text{H}_3\text{O}_2$ ; $\text{H}_2\text{O}$
$^{205}\text{Tl}$						53G12	1.009838 1	$^{203}\text{Tl}$	$\text{Hg}_2\text{O}_3+\text{HCl}+\text{HNO}_3$
$^{205}\text{Tl}$						54W37	1.009816 22	$^{203}\text{Tl}$	$\text{TlC}_2\text{H}_3\text{O}_2$
$^{205}\text{Tl}$			$\pm 1.6274\ 8$	160		63Ba23	0.57701173 4	$^1\text{H}$	$\text{TlC}_2\text{H}_3\text{O}_2$ ; $\text{H}_2\text{O}$
$^{205}\text{Tl}$							1.00983613 6	$^{203}\text{Tl}$	$\text{TlC}_2\text{H}_3\text{O}_2$

Table E: Nuclear Moments by Nuclear Magnetic Resonance — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	Diam. Cor. (nm $\times 10^4$ )	$Q$	Refer.	$\nu/\nu'$ standard	Stan-dard	Chemical Forms
$^{207}_{82}\text{Pb}$		1/2	+0.5895 3	59		50P51	0.7901 1	$^{23}\text{Na}$	$\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$ ; $\text{NaCl}$ $\text{Pb}(\text{C}_2\text{H}_5)_4$ $\text{Pb}(\text{SO}_4)$ powder, most ionic compound
			$\pm 0.5902^d$ 3	59		57Ba34	0.2092198 <sup>d</sup> 10	$^1\text{H}$	
			$\pm 0.5883^\ddagger$ 3	59		58Pi48			
$^{207}_{82}\text{Pb}$			$\pm 0.5880$ 4	59		59Ro45	1.3580 $^\ddagger$ 4	$^2\text{H}$	$\text{Pb}(\text{SO}_4)$ powder; $\text{D}_2\text{O}$ $\text{Pb}(\text{NO}_3)_2 \cdot I$ ; $\text{D}_2\text{O}$
$^{209}_{83}\text{Bi}$	>2Ay		+4.0800 21	412		51P02	1.0468 1	$^2\text{H}$	$\text{Bi}(\text{NO}_3)_3$ ; $\text{D}_2\text{O}$ $\text{Bi}(\text{NO}_3)_3$ ; $\text{D}_2\text{O}$ $\text{Bi}(\text{NO}_3)_3 \cdot 5\text{H}_2\text{O}$ ; glycerine
			$\pm 4.0802$ 20	412		53T01	1.04684 5	$^2\text{H}$	
			$\pm 4.0809$ 20	412		59F39	0.160722 14	$^1\text{H}$	

\* Polarization or Sternheimer correction included

♦ No splitting observed

† Value used in average or least squares adj.

‡ Resonance observed by depolarization of polarized nuclei ( $\gamma$ -anisotropy or  $\beta$ -asymmetry

§ Determined from broadening of resonance lines

° Recalculation of earlier data

¶ Measured by double resonance technique

· Extrapolated to zero concentration or density

· Determined from relaxation times

· Computed corrections for atomic diamagnetism and molecular paramagnetic shielding included

· Used circularly polarized rf fields

· Used optical pumping to align nuclei

· Without Knight shift correction

· Includes estimated correction for Knight shift

· Value uncorrected for diamagnetism

· Metastable or excited state

· Not certain if authors corrected for diamagnetism, therefore not corrected by compilers

· Preliminary value from meeting abstract, report, thesis, or private communication

· Determined from quadrupole splitting of the magnetic resonance

· Resonance observed by asymmetry of  $\mu$ -decay

**Table F: Nuclear Moments  
by Atomic and Molecular Beams**

### Introduction

The atomic-beam magnetic-resonance apparatus is a device for observing certain types of transitions between atomic energy states. These transitions, usually associated with ground-state levels, can be studied in fields ranging from weak (small fractions of a gauss) to strong (several kilogauss). The basic principles of the method are discussed extensively in *Atomic and Molecular Beam Spectroscopy*, P. Kusch and V. W. Hughes [59Ku94], *Nuclear Moments*, H. Kopfermann [58Ko90], *Molecular Beams*, N. F. Ramsey [56Ra58], and *Molecular Beams*, K. F. Smith [55Sm12].

The precision attainable by this method is associated with the factors: (1) the atom is not perturbed by adjacent atoms or collisions with apparatus walls, (2) the natural lifetime of the energy state is usually extremely long compared with any time constant of the apparatus, and (3) the transit time through the transition region can be made as long as many tens of milliseconds.

The total energy of an atomic level, neglecting interactions with an applied magnetic field, can be expressed as

$$W = W_J + W_{M1} + W_{E2} + W_{M3} + \dots, \quad (1)$$

where  $W_J$  is the energy independent of the interactions with the nuclear moments and  $W_{M1}$ ,  $W_{E2}$ ,  $W_{M3}$  are the energies due to the interaction of the electrons with the nuclear magnetic dipole, electric quadrupole, and magnetic octupole moments, respectively.

The magnetic dipole term can be expressed as

$$W_{M1}/h = aIJ\cos(IJ) = (a/2)[F(F+1) - I(I+1) - J(J+1)]. \quad (2)$$

The existence of this term causes a particular atomic level to be split into  $2I+1$  or  $2J+1$  hyperfine levels depending upon whether  $I < J$  or  $J < I$ . The hyperfine-structure splitting is defined by  $\Delta\nu = \Delta W/h$ , where  $\Delta W$  is the energy separation of a pair of hyperfine levels with total spins  $F$  and  $(F-1)$  measured at zero magnetic field. From eq. (2), the hyperfine-structure splitting between such a pair of levels for a state with no quadrupole interaction is just  $\Delta\nu(F, F-1) = Fa$ .

The magnetic interaction constant  $a$  can be shown to be equivalent to  $\mu_i H(0)/hIJ$  where  $H(0)$  represents the time-averaged magnetic field at the nucleus due to the electron distribution. The precision with which  $\mu_i$  can be determined from  $a$  is limited by the precision with which the atomic wavefunctions are known to permit the calculation of  $H(0)$ . The

uncertainty in  $H(0)$  may be of the order of a few percent.

In practice, the magnetic moment of a nucleus can be determined indirectly provided one isotope of that element has been studied by another method such as nuclear resonance. The relationship  $\mu_1/\mu_2 = a_1 I_1/a_2 I_2$ , which is based on the assumptions that the electronic wavefunctions and nuclear fields are the same for both isotopes, can be used to evaluate  $\mu$ . It has been shown experimentally that these two ratios are not exactly equal. The hyperfine-structure anomaly, which is defined by  $^1\Delta^2 = (a_1 I_1 \mu_2/a_2 I_2 \mu_1) - 1$ , has been found to be as large as 1% for some pairs of isotopes. A tabulation of experimentally determined magnetic hyperfine structure anomalies may be found in a report by Fuller and Cohen [70FuCo]. More precise methods of determining  $\mu$  will be discussed later.

The electric quadrupole term in (1) is given by

$$W_{E2}/h = (b/4)[(^3/2)K(K+1) - 2I(I+1)J(J+1)] \times [I(2I-1)J(2J-1)]^{-1} \quad (3)$$

which, in the classical limit, becomes

$$W_{E2}/h = (b/4)[(3/2)\cos^2(IJ) - 1/2]$$

where  $b = e(\partial E/\partial z)(Q/h)$  and

$$K = F(F+1) - I(I+1) - J(J+1).$$

The calculation of  $Q$  from the quadrupole interaction constant  $b$  is limited by the accuracy in the determination of  $\partial E/\partial z$  at the nucleus. The uncertainty in the atomic wavefunctions may introduce uncertainties in  $\partial E/\partial z$  of a few percent. In addition, the nuclear quadrupole moment causes a polarization of the atomic core electrons (Sternheimer effect). The effect of this polarization on the calculation of  $\partial E/\partial z$  at the nucleus may be included as a correction factor which can amount to tens of percent. In compiling the following table, no attempt has been made to apply the Sternheimer correction where the authors have not done so. For any precise application of quadrupole data, one should refer to the original experimental work and to the references on the necessary corrections [66St23].

A severe limitation of the atomic-beam method for the measurement of electric quadrupole interactions is due to the fact that most beam experiments are performed on atoms in the ground state, which in many cases is an S state. In such a state, there is no interaction with the nuclear quadrupole moment. It is possible, however, to perform atomic-beam experiments on such atoms if they have been excited by absorption of optical resonance radiation or by electron impact.

The magnetic octupole term in (1) is given by

$$\begin{aligned}
 W_{M_3}/h = & (5c/4)[K^3 + 4K^2 + (4/5)K\{-3I(I+1)J(J+1) \\
 & + I(I+1) + J(J+1) + 3\} - 4I(I+1)J(J+1)] \\
 & \times [I(I-1)(2I-1)J(J-1)(2J-1)]^{-1} \quad (4)
 \end{aligned}$$

where  $c$  is the magnetic octupole interaction constant from which the magnetic octupole moment  $\Omega$  can be calculated. In the classical limit, equation (4) can be written as

$$W_{M_3} = (1/3)\Omega(\partial^2 H(0)/\partial z^2)_{ave}[(5/2)\cos^3(IJ) - (3/2)\cos(IJ)].$$

The magnetic octupole interactions so far reported are of the order of 100 Hz or less than  $10^{-6}$  times the dipole interactions. It is therefore necessary to evaluate the first two moments to a very high precision and include perturbation effects of low-lying excited states in order to compute  $\Omega$  from  $c$ .

In the presence of a magnetic field  $H$ , additional terms for the direct interaction of the electronic and nuclear magnetic moments with the field must be included. The direct interaction term is given by

$$W_H = \mu_B g_J J \cdot H + \mu_B g'_I I \cdot H, \quad (5)$$

where  $g_J = -\mu_J/J\mu_B^{-1}$ ,  $g'_I = -\mu_I/I\mu_B^{-1}$ , and  $\mu_B$  is the Bohr magneton.

Energy differences between two states are given by the measured frequencies of the oscillating field (described below) which produces transitions between those states. By measuring these energy differences,  $I$ ,  $g_J$ ,  $a$ ,  $b$ , and sometimes  $g'_I$  and  $c$  can be determined. In principle, these can then be used to calculate the nuclear moments  $\mu$ ,  $Q$ ,  $\Omega$ .

In the relatively simple case of an atom in an  $S_{1/2}$  state, the energy dependence of a hyperfine level as a function of  $H$  can be expressed by the Breit-Rabi equation

$$\begin{aligned}
 W = & -(\Delta W/[2(2I+1)]) + m_F g' \mu_B H \\
 & \pm (\Delta W/2)[1 + 4m_F x/(2I+1) + x^2]^{1/2},
 \end{aligned}$$

where  $\Delta W$  is the energy splitting of the  $^2S_{1/2}$  state caused by the nuclear field and  $x = (g_J - g'_I) \mu_B H / \Delta W$ . Figure 2 illustrates graphically the function  $W/\Delta W$  for an atom in the  $^2S_{1/2}$  state with a nucleus with  $I = 4$ , and  $\mu > 0$ .

A common arrangement of an atomic-beam magnetic-resonance system is shown in figure 1. The apparatus consists essentially of

- (1) A source of neutral atoms at thermal energies.
- (2) A detector of atomic-beam intensity.
- (3) A pair of deflecting magnets (A and B of figure 1). In the regions A and B, the magnetic fields have a large field gradient so that the atoms will experience a transverse force,  $F = -\partial W/\partial z = -(\partial W/\partial H) \times (\partial H/\partial z)$ .
- (4) A uniform adjustable magnetic field (C-field in figure 1). In this region, oscillating magnetic radiation can be introduced to cause transitions from one magnetic state to another.

In a strong field, the atomic state is characterized by magnetic quantum numbers  $m_I$  and  $m_J$ . For an atom in an  $S_{1/2}$  state,  $m_J$  can take on the values  $+1/2$  or  $-1/2$ . In the nonuniform A and B magnetic fields, atoms in the  $m_J = +1/2$  states will be deflected toward the weak field (paths a, figure 1), while those in the  $m_J = -1/2$  states will be deflected toward the strong field (paths b, figure 1). If, while in the C-region, an atom undergoes a transition from any of the magnetic substates associated with  $m_J = \pm 1/2$  to one with  $m_J = \mp 1/2$  (such as transitions  $\alpha$ ,  $\beta$ ,  $\gamma$ ,  $\delta$ , or  $\epsilon$ , figure 2), the deflection in the B-field will be opposite to that in the A-field and the atom will then be focused onto the detector. Such a transition can be induced if the frequency  $\nu$  of the applied oscillating field satisfies the condition  $W_1 - W_2 = \hbar\nu$ , where  $W_1 - W_2$  is the energy separation of the two levels. This resonant frequency condition is observed by the accompanying maximum in beam intensity at the detector. From the observed resonant frequencies, the energy differences between pairs of states are determined and the quantities  $I$ ,  $g_J$ ,  $a$ ,  $b$ , and sometimes  $g'_I$  and  $c$  can be derived. The nuclear moments  $\mu$ ,  $Q$ , and  $\Omega$  can then be calculated from the interaction constants by use of the best available atomic wavefunctions. The magnetic dipole is the only moment which interacts directly with the applied magnetic field  $H$  and can thus be determined by very precise measurements of the appropriate energy separations.

In a magnetic field of a few gauss, where the variation of the energies of the individual  $m_F$ -states with respect to  $H$  is practically linear, the level separation is a function of  $I$  and  $H$  only. The observation of a transition such as  $\alpha$ , in figure 2, can serve to determine  $I$  with no ambiguity.

In the intermediate field region, the energy expression for the transition  $\beta$ , figure 2, has terms non-linear in  $H$  which are functions of  $\Delta W$ , the hyperfine-structure splitting. A measurement of this transition at such fields can permit calculation of  $\Delta W$

<sup>1</sup> Since the orientation of the spin and the associated magnetic moment are antiparallel for the electron and parallel for the proton, there is much confusion regarding the convention for signs of  $g_S$  and  $g_I$ , the g-factors of an electron and a nucleus, and of  $\mu_S$  and  $\mu_I$ , the corresponding magnetic moments. There are variations in the literature, and some authors are not self-consistent. The convention adopted here is that  $g_S$  is positive for the electron (where  $\mu_S$  is negative, i.e. antiparallel to the spin) and  $g'_I$  is positive for a nucleus when  $\mu_I$  is negative or antiparallel to the nuclear spin.

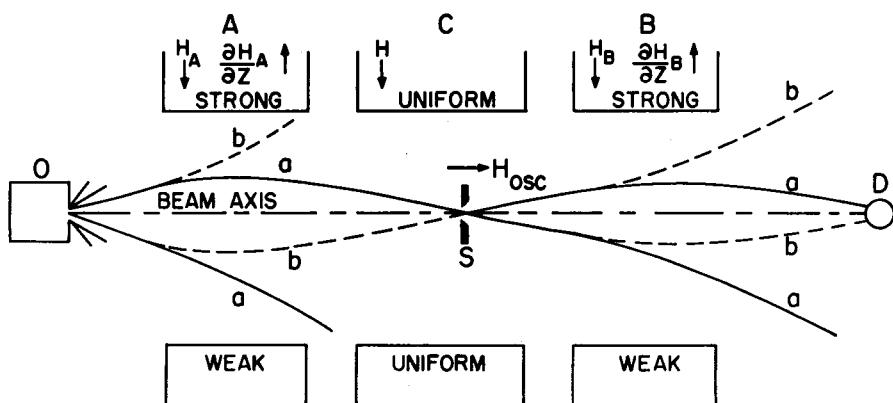


FIGURE 1. Schematic diagram of atomic beam apparatus. O—oven; S—slit; D—detector; A and B—regions with fields and field gradients in directions indicated; C—region with uniform field  $H$  and oscillating field  $H_{osc}$  in directions indicated: "a" and "b" represent paths of atoms with negative and positive effective magnetic moments, respectively.

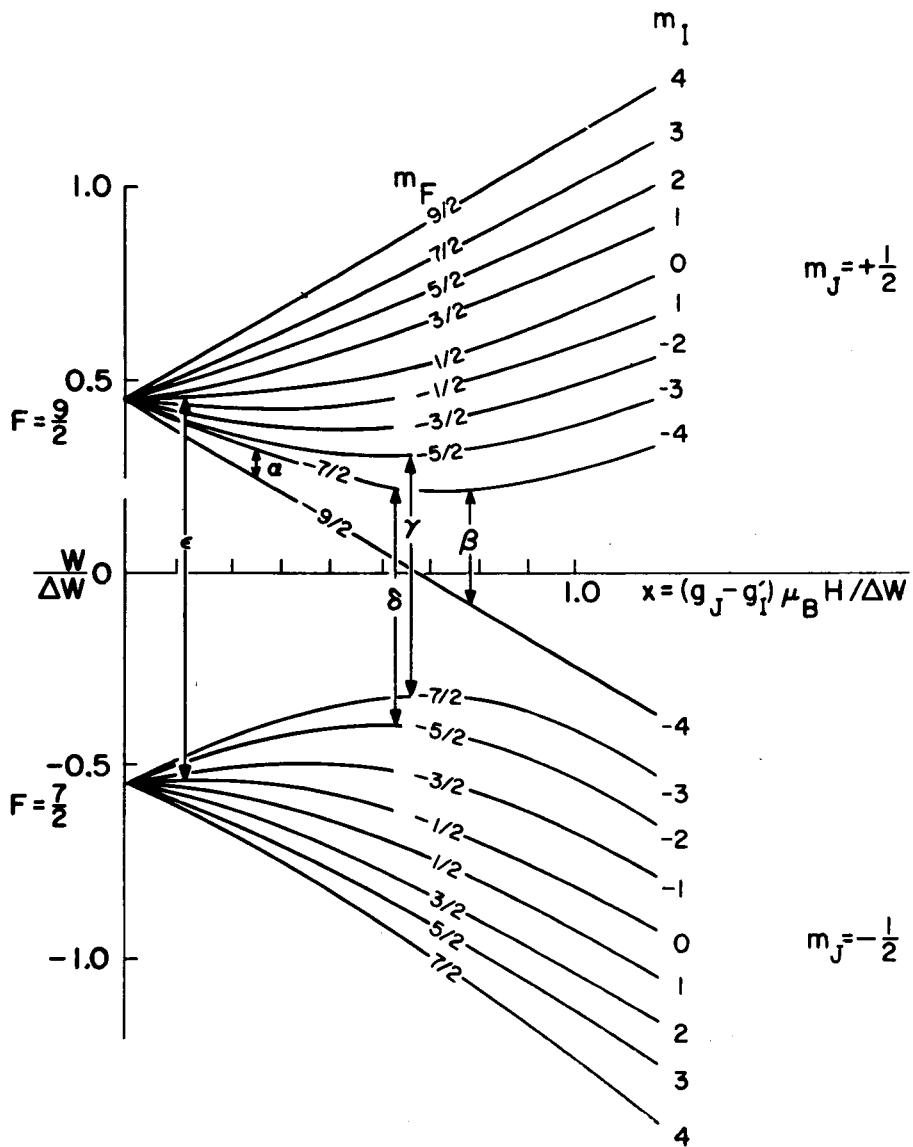


FIGURE 2. Breit-Rabi diagram of the energy levels of an atom in a  $^2S_{1/2}$  state with a nucleus with  $I=4$  and  $\mu>0$ .  $\alpha$ ,  $\beta$ ,  $\gamma$ ,  $\delta$ , and  $\epsilon$  represent some of the observable transitions which are useful for the determination of nuclear properties as explained in text.

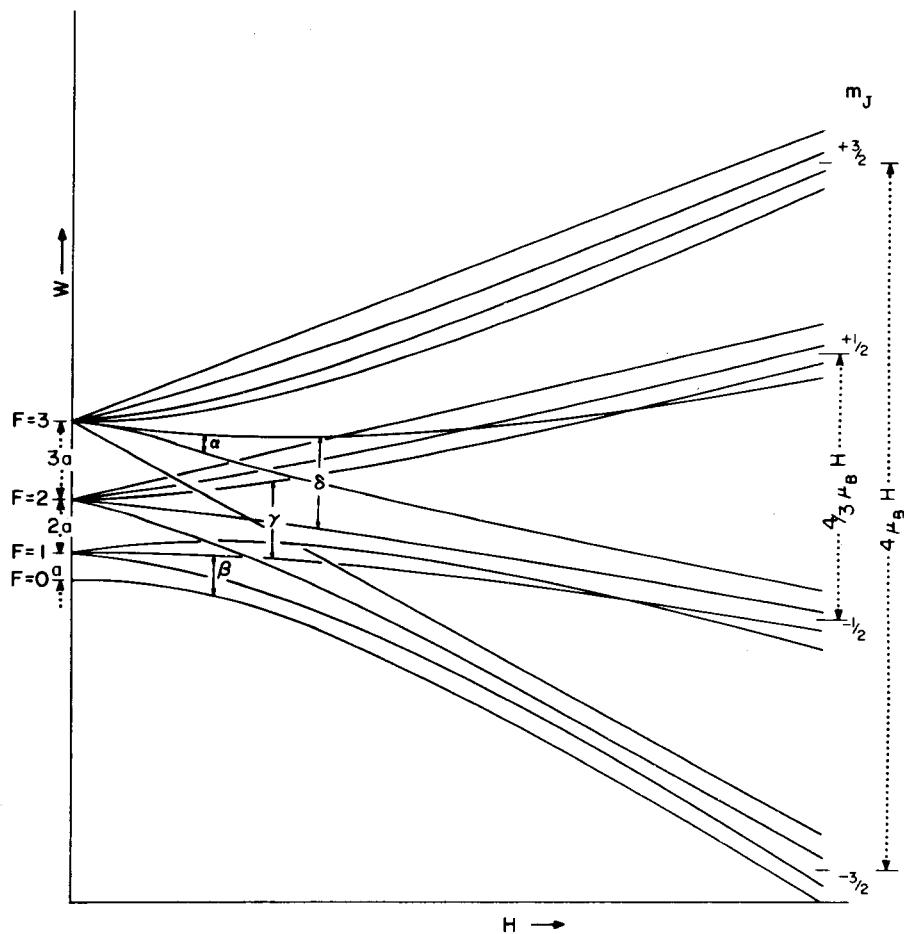


FIGURE 3. Schematic diagram of the energy levels of an atom in a  $^2P_{3/2}$  state with a nucleus with  $I = 3/2$ ,  $\mu > 0$ ,  $Q = 0$ . Transitions  $\alpha$ ,  $\beta$ ,  $\gamma$ , and  $\delta$  may be used to determine the nuclear moments.

with moderate accuracy. Measurement of the field independent transition  $\epsilon$ , figure 2 [ $F = ^3/2$ ,  $m_F = +1/2 \leftrightarrow F = ^7/2$ ,  $m_F = -1/2$ ], at very low field gives a measure of  $\Delta W$  good to a precision of 1 part in  $10^{10}$ .<sup>2</sup>

At intermediate fields the transitions  $\gamma$  and  $\delta$ , figure 2, pass through frequency minima and at such fields their low field dependence permits very sharp lines to be obtained. For  $J = 1/2$  states, the difference between these two lines is exactly  $2g'_1\mu_B H$  so that  $g'_1$  can be determined directly. In practice this evaluation of  $g'_1$  is limited by the precision with which one can evaluate  $H$ . Since  $H$  is usually measured in terms of a transition such as  $\beta$ , which depends on  $g_J$ ,

the determination of  $g'_1$  can be reduced to a measurement of the ratio  $g'_1/g_J$ .

In all nuclear magnetic moment measurements the measured quantity is  $\mu_I H/I$  where  $H$  is the field at the nucleus.  $H$  differs from the applied field by the field induced by the core electrons. Unfortunately, this effect cannot be measured and the early general calculations of the diamagnetic corrections [41La03], [50Di10], [64Bo38] were assumed to have uncertainties of the order of 5%. The values of this correction range from 0.0006% for He to 1.16% for U. The tabulated magnetic moments include the corrections based on values in [50Di10]. More recent calculations of Lin, Feick, and Johnson [72Jo18] yield values of the diamagnetic correction which are larger than those used (up to a factor of 2 larger for the heaviest atoms). The values of the correction factors used in the tables, as well as those of [72Jo18], have been tabulated in section 2 under Diamagnetic corrections.

A more complex case is illustrated in figure 3 drawn for a  $^2P_{3/2}$  state and a nucleus with a spin of  $3/2$ , positive magnetic moment, and no quadrupole moment. The field dependence of transition  $\alpha$  can be used to determine the nuclear spin  $I$ . Transitions  $\beta$ ,

<sup>2</sup>The measurement of a frequency with a stated accuracy in terms of Hz presupposes that the second is determinate to an accuracy greater than that of the measurement. The second of time defined in terms of the rotation of the earth (Universal Time, UT1) is subject to difficult corrections for varying angular velocity of the earth, which can amount to 50 parts in  $10^{10}$  per year. Measurements of the  $^{133}\text{Cs}(4,0 \leftrightarrow 3,0)$  hyperfine-structure splitting made in 1955 gave an approximate value of 9,192,631,840 Hz of UT [57Es32] which was adopted as a provisional definition of the second. Since then, however, a more precise measurement has been made in terms of Ephemeris Time (ET) which is not subject to the fluctuations in the earth's rotation. The value of the  $^{133}\text{Cs}$  hyperfine-structure splitting has been determined as  $9,192,631,770 \pm 20$  Hz of ET as measured at the year 1957.0 [58Ma18]. The definition of the second of Atomic Time (AT), adopted by the 13th General Conference of Weights and Measures (Paris, October 1967) and reported by Terrien [68Te02], is given in terms of  $\Delta\nu(^{133}\text{Cs}) = 9,192,631,770$  Hz.

$\gamma$ , and  $\delta$  can be used to evaluate the separations  $\Delta W(0,1)$ ,  $\Delta W(1,2)$ , and  $\Delta W(2,3)$ , respectively. If there were an electric quadrupole moment, the zero-field separations would be modified as shown in equation

(3). In the  $P_{3/2}$  state the evaluation of  $\mu$  from doublet separations is not as simple as in the  $^2S_{1/2}$  case.

The last systematic literature search for information included in the table was in early 1971.

### Explanation of Table F

Nucleus	Chemical symbol with $Z-$ and $A-$ number States, other than ground states, are designated by "m" following the $A-$ number.
$T_{1/2}$	Half-life of radioactive nucleus
$I$	Nuclear spin, in units of $h/2\pi$
$\mu$	Nuclear magnetic dipole moment, in nuclear magnetons, given with diamagnetic correction. See Policies, Diamagnetic corrections, for factors used A 5% uncertainty in the diamagnetic correction is assumed.
	Values of $\mu$ calculated from $\Delta\nu-$ or $a-$ ratios do not include a hyperfine-structure anomaly correction unless so designated by a footnote. This correction can be the order of 0.001% to 1%. See [70FuCo].
	Values of the magnetic octupole moment, in nuclear magneton-barns, are also tabulated in this column with the notation " $\Omega=...$ ".
$Q$	Nuclear electric quadrupole moment, in barns, as given by the experimenter Values marked by an asterisk, *, indicate that the experimenter has made some polarization or Sternheimer correction in computing the moment. Values of the electric hexadecapole moment, given in $10^{-2}b^2$ , are also tabulated in this column with the notation " $Q_4=...$ ".
Refer.	Reference key
Atomic State	Atomic state for which the hyperfine-structure splitting and the interaction constants are listed
$F, F'$	Total angular momentum quantum numbers which characterize hyperfine levels of the atomic state at zero magnetic field
$\Delta\nu(F, F')$	The zero-field hyperfine-structure splitting between levels of total spin $F$ and $F'$ , given without sign Values are given in MHz unless otherwise noted.
Molecule Used	For molecular beam experiments, the formulae of the compounds used
Interaction Constants	Values of the interaction constants, $a$ , $b$ , and $c$ , as given by the experimenter Values are given in MHz unless otherwise noted.
	When the nuclear $g$ -factor is measured directly from the resonance frequencies or doublet separations, it is also tabulated, in Bohr magnetons.
Moment Ratios	Magnetic and electric moment ratios as determined by molecular beam techniques Superscripts on the moment symbols designate $A$ -values of isotopes
	Quadrupole interactions, $eqQ/h$ , are also tabulated in MHz

**Table F: Nuclear Moments by Atomic and Molecular Beams**

Table F: Nuclear Moments by Atomic and Molecular Beams - Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^7_3\text{Li}$				-0.043 <sup>c</sup>	64Br36		LiD, LiH	
$^7_3\text{Li}$					64Br37		$\text{Li}_2$	$eqQ=0.068 \pm 2$
$^7_3\text{Li}$				-0.045 <sup>e</sup> 4	64Wh01		‡Zero external field	
$^7_3\text{Li}$					66Sc29	$^2\text{S}_{1/2}: 2, 1$	$^7\text{LiH}$	$eqQ=0.355 \pm 2$
$^7_3\text{Li}$				-0.043* <sup>c</sup> 3	70Lu04		$^7\text{LiF}$	$eqQ=0.41602 \pm 6$
$^9_4\text{Be}$			-1.176 5		39K09		LiH	
$^9_4\text{Be}$				+0.049 3	67Bl09	$^3\text{P}_2: ^7/2, ^5/2$	$\text{NaBeF}_3, \text{KBeF}_3$	$g/g(^7\text{Li})=0.3613 \pm 1$
				+0.053* <sup>c</sup> 3		$^5/2, ^3/2$	435.4773 21	$a=-124.5368 \pm 17$
						$^3/2, ^1/2$	312.0226 21	$b=+1.429 \pm 8$
						$^3\text{P}_1: ^5/2, ^3/2$	187.6157 42	
						$^3/2, ^1/2$	354.4365 27	$a=-139.373 \pm 12$
							202.9529 15	$b=-0.753 \pm 44$
$^{10}_5\text{B}$			+1.794 9		39M05		several molecules	$g/g(^7\text{Li})=0.2755 \pm 15$
$^{10}_5\text{B}$				+0.0740 5	53W46			
					(52D21)			
$^{10}_5\text{B}$				+0.0804* <sup>c</sup> 16	60Le05	$^2\text{P}_{1/2}: ^7/2, ^5/2$	429.048 3	$(Q^{10}/Q^{11})=2.084 \pm 2$
$^{10}_5\text{B}$				+0.08745* <sup>c</sup>	68Sc18			
$^{10}_5\text{B}$				+0.08472* <sup>c</sup> 56	69Sc34			
$^{11}_5\text{B}$			+2.686 8		70Ne21			
$^{11}_5\text{B}$					39M05		several molecules	$g/g(^7\text{Li})=0.825 \pm 2$
$^{11}_5\text{B}$				+0.0355 2	53W46	$^2\text{P}_{3/2}: 3, 2$	222.737 10	$a=+73.347 \pm 6$
						$2, 1$	144.00 2	$b=+2.695 \pm 16$
						$1, 0$	70.66 20	
$^{11}_5\text{B}$					60Le05	$^2\text{P}_{1/2}: 2, 1$	732.4 1	
$^{11}_5\text{B}$					62Ko22	$^2\text{P}_{1/2}: 2, 1$	732.153 3	
$^{11}_5\text{B}$				+0.0357 <sup>c</sup>	68Sc18			
$^{11}_5\text{B}$				+0.0386* <sup>c</sup> 8	69Go12			
$^{11}_5\text{B}$				+0.037* <sup>c</sup> 4	69Sc34			
$^{11}_5\text{B}$				+0.04196* <sup>c</sup>	70Ne21			
$^{11}_5\text{B}$				+0.04065* <sup>c</sup> 26				
$^{11}_6\text{C}$	21m	3/2			61Sn01			
$^{11}_6\text{C}$	21m		$\pm 1.027 \pm 10$	$\pm 0.0308 \pm 6$	64Ha46	$^3\text{P}_2: ^7/2, ^5/2$	243.080 30	$a=68.203 \pm 7$
			$\mu/Q$ negative			$^5/2, ^3/2$	167.402 30	$b=4.949 \pm 28$
						$^3\text{P}_1: ^5/2, ^3/2$	-0.200 50	$a=1.242 \pm 10$
							or +0.062 50	or 1.200 10
$^{11}_6\text{C}$	21m		$\pm 0.997^c$	$\pm 0.0322*^c 6$	68Sc18			
$^{11}_6\text{C}$	21m		$\pm 0.97^c 6$	$\pm 0.031*^c \pm 3$	69Go12		‡For $\mu < 0$	
$^{11}_6\text{C}$	21m		$\pm 1.015^c$	$\pm 0.03426*^c$	69Sc34			
$^{11}_6\text{C}$	21m		(-?)0.964 <sup>c</sup> ± 1		70Woll	$^3\text{P}_1$		$a=-1.308^c 24$
								or +1.202 <sup>c</sup> 24
								‡From comparison with
								$a(^3\text{P}_1)/a(^3\text{P}_2)$ for $^{13}\text{C}$ , find
								$a(^3\text{P}_1) \sim -1.30$
$^{13}_6\text{C}$			+0.7018 20		41H14		$\text{K}^{13}\text{CN}, \text{Na}^{13}\text{CN}$	$g/g(^7\text{Li})=0.6464 \pm 18$
$^{13}_6\text{C}$					70Woll	$^3\text{P}_1: ^3/2, ^1/2$	4.257 25	$a=2.838 \pm 17$
						$^3\text{P}_2: ^5/2, ^3/2$	372.636 25	$a=149.055 \pm 10$
$^{13}_7\text{N}$	10m	1/2			61Sn01			
$^{13}_7\text{N}$	10m	1/2	$\pm 0.32212^a 36$		64Be24	$^4\text{S}_{3/2}: 2, 1$	33.347 20	$a=16.673 \pm 10$

Table F: Nuclear Moments by Atomic and Molecular Beams - Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^{14}_7\text{N}$			+0.403 2		39K10		NaCN, KCN	$\mu/\mu(^7\text{Li})=0.1237$ 6
$^{14}_7\text{N}$					70Cr02	$^4\text{S}_{3/2}$		$a=10.45092906$ 1 19
$^{15}_7\text{N}$			$\pm 0.280$ 3		40Z02		$^{15}\text{N}_2$	$b=+1.32$ 1 20 Hz
$^{15}_8\text{O}$	2.1m	1/2	$\pm 0.7189$ * 8		63Co17	$^3\text{P}_2, ^5/2, ^3/2$	1037.23 7	$a=414.87$ 3 $a(^{17}\text{O})=218.569$ 10
$^{19}_9\text{F}$			+2.625 2		41M08		NaF	$g=5.248$ 5 nm
$^{19}_9\text{F}$					61Ra14	$^2\text{P}_{3/2}, 2, 1$	4020.01 $\pm$ 2	$\ddagger$ Hyperfine splitting obtained by paramagnetic resonance experiment
$^{19}_9\text{F}$			$\pm 2.6289$ 9		64Bo37		TlF	
$^{19}_{10}\text{Ne}$	18s	1/2 <sup>f</sup>	-1.887 1		63Co22	$^1\text{S}_0$		$\nu/\nu(^1\text{H})=0.6754$ 2
$^{20}_{10}\text{Ne}$	0*		$\leq 4 \times 10^{-4}$ , if $I=1$		60Lu06			$a < 250$ kHz
$^{21}_{10}\text{Ne}$		3/2			56H70	$^3\text{P}_2$		
$^{21}_{10}\text{Ne}$			-0.66176 2	+0.093 10	57L08		20.5% $^{21}\text{Ne}$	$g/g(^2\text{H})=0.514274$ 4
$^{21}_{10}\text{Ne}$					58G65	$^3\text{P}_2, ^7/2, ^5/2$ $^5/2, ^3/2$ $^3/2, ^1/2$	1034.48 10 599.44 10 303.93 10	$a=-267.68$ 3 $b=-111.55$ 10
$^{23}_{10}\text{Ne}$	38s		-1.08 1		68Do07			
$^{21}_{11}\text{Na}$	23s	3/2	+2.38612 * 10		65Am01	$^2\text{S}_{1/2}, 2, 1$	1906.466 21	
$^{22}_{11}\text{Na}$	2.6y	3	+1.746 * 3		49D01	$^2\text{S}_{1/2}, ^7/2, ^5/2$	1220.64 4	
$^{23}_{11}\text{Na}$		3/2 <sup>b</sup>			34R01			
$^{23}_{11}\text{Na}$			+2.215 2		41M08		Na <sub>2</sub>	$g=1.4761$ 15 nm
$^{23}_{11}\text{Na}$			$\pm 2.2175$ 2	+0.108 12	51L28	$^2\text{S}_{1/2}, 2, 1$	1771.631 2	$g/g(^1\text{H})=0.26451$ 2
$^{23}_{11}\text{Na}$				or -0.909 30	55P33	$^2\text{P}_{3/2}$		$a=19.06$ 36 $b=+2.58$ 30 or $b=-21.64$ 70 $a=94.45$ 50
$^{23}_{11}\text{Na}$						$^2\text{P}_{1/2}$		
$^{23}_{11}\text{Na}$				+0.087 * 10	60Be34			
$^{23}_{11}\text{Na}$				+0.103 <sup>c</sup>	62Ko22			
$^{23}_{11}\text{Na}$					64Br37		Na <sub>2</sub>	$eqQ=0.424$ $\ddagger$ 2
$^{23}_{11}\text{Na}$							$\ddagger$ Zero external field	
$^{23}_{11}\text{Na}$					70Ch40	$^2\text{S}_{1/2}, 2, 1$	1771.6261275 <sup>p</sup> 5	
$^{23}_{11}\text{Na}$					73Co35			
$^{23}_{11}\text{Na}$			$\pm 2.21740$ <sup>d,p</sup> 7		71Co34	$^2\text{S}_{1/2}$		
$^{23}_{11}\text{Na}$					73Co35			
$^{24}_{11}\text{Na}$	15h	4	+1.689 * 5		53B19	$^2\text{S}_{1/2}, ^9/2, ^7/2$	1139.35 10	
$^{24}_{11}\text{Na}$	15h		+1.6902 <sup>d</sup> 10		66Ch15	$^2\text{S}_{1/2}, ^9/2, ^7/2$	1139.33258 10	
$^{24}_{11}\text{Na}$					73Co36			
$^{25}_{12}\text{Mg}$			-0.855 2	+0.22	59K82	$^1\text{S}_0$		$g/g(^1\text{H})=0.612$
$^{25}_{12}\text{Mg}$					62Lu04	$^3\text{P}_2, ^9/2, ^7/2$ $^7/2, ^5/2$ $^5/2, ^3/2$ $^3/2, ^1/2$	567.291 10 452.338 10 329.044 10 199.82 4	$a=-128.440$ 5 $b=16.009$ 5
$^{25}_{12}\text{Mg}$						$^3\text{P}_1, ^7/2, ^5/2$ $^5/2, ^3/2$	516.140 10 349.987 10	$a=-144.945$ 5 $b=-8.029$ 5
$^{27}_{13}\text{Al}$		5/2	+3.637 10		39M08		NaCl-AlCl <sub>3</sub>	$g/g(^7\text{Li})=0.6696$
$^{27}_{13}\text{Al}$		5/2		+0.156 3	49L15	$^2\text{P}_{3/2}, 4, 3$ 3, 2	392.0 2 274.3 1	$a=94.25$ 4 $b=18.76$ 25
$^{27}_{13}\text{Al}$				+0.155 <sup>e</sup>	52K10			

Table F: Nuclear Moments by Atomic and Molecular Beams — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^{27}_{13}\text{Al}$				+0.149 2	53L15	$^2\text{P}_{1/2}: 3, 2$	1506.14 5	$a=502.05$ 2
$^{27}_{13}\text{Al}$				+0.150 <sup>c</sup>	62Ko22 (53L15) 68Ma23	$^2\text{P}_{3/2}$		$a=94.27767^{\text{E}}$ 10 $b=18.9153^{\text{E}}$ 7
$^{27}_{13}\text{Al}$				$\pm 0.140^{\ast \text{c}} 2$	71St44			
$^{30}_{15}\text{P}$	2.6m	1			68Ph02	$^4\text{S}_{3/2}$		$a=+55.061$ 10
$^{31}_{15}\text{P}$					64Pe11			
$^{35}_{17}\text{Cl}$		3/2	positive	-0.0795 5	49D14	$^2\text{P}_{3/2}$		$a=205.288$ 10
$^{35}_{17}\text{Cl}$				-0.07894 2	51J20	$^2\text{P}_{3/2}$		$b=55.347$ 20, $b/a>0$
$^{35}_{17}\text{Cl}$								$a=205.050$ 5
$^{35}_{17}\text{Cl}$				$\pm 0.82$ 8	51K31	$^2\text{P}_{1/2}: 2, 1$	2074.383 8	$b=54.873$ 5
$^{35}_{17}\text{Cl}$				-0.0782 <sup>c</sup>	52K10			$Q^{35}/Q^{37}=1.2686$ 4
$^{35}_{17}\text{Cl}$				$\Omega=-0.0191$ 32	56Ho02	$^2\text{P}_{3/2}: 3, 2$ 2, 1 1, 0	670.013455 90 355.221030 70 150.173560 75	$a=205.046870$ 30
$^{35}_{17}\text{Cl}$				$\Omega=-0.0188^{\ast}$ 30	57S28			$b=54.872905$ 55
$^{35}_{17}\text{Cl}$					62Ko22 (51J20)			$c=-7.15$ 120Hz
$^{35}_{17}\text{Cl}$				-0.0793 <sup>c</sup>				$(c=9.3^{\text{j}}$ 12Hz)
$^{35}_{17}\text{Cl}$				$\Omega=-0.0188^{\ast}$	71Am02	$^2\text{P}_{3/2}$		$c=-6.95$ 120Hz
$^{35}_{17}\text{Cl}$				$\Omega=-0.0162^{\ast \text{c}}$	(49D14)			
$^{37}_{17}\text{Cl}$		3/2		-0.0621 5	49D14	$^2\text{P}_{3/2}$		$a=205.046860^{\ast}$
$^{37}_{17}\text{Cl}$				-0.06213 2	51J20	$^2\text{P}_{3/2}$		$b=54.872934^{\circ}$
$^{37}_{17}\text{Cl}$					51K31	$^2\text{P}_{1/2}: 2, 1$	1726.700 15	$c=-7.015^{\circ}$ Hz
$^{37}_{17}\text{Cl}$				$\pm 0.68^{\ast}$ 7	52K10			$a=170.686$ 10
$^{37}_{17}\text{Cl}$				-0.0616 <sup>c</sup>	56Ho02	$^2\text{P}_{3/2}: 3, 2$ 2, 1 1, 0	555.304315 90 298.127655 70 127.440815 75	$b=43.256$ 20, $b/a>0$
$^{37}_{17}\text{Cl}$				$\Omega=-0.0148$ 32				$a=170.681$ 10
$^{37}_{17}\text{Cl}$								$b=43.255$ 10
$^{37}_{17}\text{Cl}$				$\Omega=-0.0146^{\ast}$ 30	57S28			
$^{35}_{18}\text{Ar}$	1.8s	3/2 <sup>f</sup>	+0.632 2		65Ca04			
$^{39}_{19}\text{K}$	7.7m	3	+1.3740 <sup>a</sup> 10		65Ph02	$^2\text{S}_{1/2}: ^7/2, ^5/2$	1415.292 9	
$^{39}_{19}\text{K}$		3/2 <sup>b</sup>	$\pm 0.397$		35M08	$^2\text{S}_{1/2}$		
$^{39}_{19}\text{K}$			positive		37T04			
$^{39}_{19}\text{K}$				+0.391 2	39K10			
$^{39}_{19}\text{K}$					50O01	$^2\text{S}_{1/2}$		$g/g(^7\text{Li})=0.120$
$^{39}_{19}\text{K}$					52E09	$^2\text{S}_{1/2}$		$g^{39}/g^{41}=1.8218$ 2
$^{39}_{19}\text{K}$				$\pm 0.39149^{\text{d}}$ 15	57B19	$\text{P}_{1/2}$ $\text{P}_{3/2}$		$g^{40}/g^{39}=1.24346^{\text{d}}$ 24
$^{39}_{19}\text{K}$				$\pm 0.07$ 2				$a=28.85$ 3
$^{39}_{19}\text{K}$					59M70	$^2\text{S}_{1/2}: 2, 1$	461.71971 15	$a_{3/2}=5a_{1/2}$ assumed
$^{39}_{19}\text{K}$				+0.070 <sup>c</sup>	62Ko22 (57B19)			$b=2.8$ 8
$^{39}_{19}\text{K}$					67Da04	$^2\text{S}_{1/2}: 2, 1$	461.719723 38	

Table F: Nuclear Moments by Atomic and Molecular Beams — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^{39}_{19}\text{K}$				+0.053 8	68Sp03	$^4\text{F}_{9/2}; 6, 5$ $^4\text{D}_{7/2}$	568.8 1	$a=103.56\ 9$ $b=78.86\ 80, b/a < 0$ $a=150.03\ 90$ $b=78.5\ 32, b/a < 0$ $a=+6.10\ 25$ $b=+1.8\ 12$
$^{39}_{19}\text{K}$					69Zi01	$^4\text{P}_{3/2}$		
$^{39}_{19}\text{K}$					70Ch40 73Co35	$^2\text{S}_{1/2}; 2, 1$	461.7197204 <sup>p</sup> 5	
$^{39}_{19}\text{K}$	1.3Gy	4	$\pm 0.391427^{dp} 27$		73Co35			
$^{40}_{19}\text{K}$	1.3Gy		-1.291 <sup>a</sup> 5		49D01	$^2\text{S}_{1/2}; ^9/2, ^7/2$	1285.73 5	
$^{40}_{19}\text{K}$			-1.2981 <sup>d</sup> 4		52E09	$^2\text{S}_{1/2}; ^9/2, ^7/2$	1285.790 7	
$^{41}_{19}\text{K}$		3/2 <sup>b</sup>			36M03			
$^{41}_{19}\text{K}$					53L33		$^{39}\text{KCl}, ^{41}\text{KCl}$	$Q^{41}/Q^{39}=1.220^{\text{E}} 2$
$^{41}_{19}\text{K}$			$\pm 0.2153^{a, d} 4$		60Sa23	$^2\text{S}_{1/2}; 2, 1$	254.014 1	
$^{41}_{19}\text{K}$					67Bo40		$^{39}\text{KF}, ^{41}\text{KF}$	$Q^{39}/Q^{41}=+0.8215^{\text{E}} 1$
$^{41}_{19}\text{K}$					70Ch40 73Co35	$^2\text{S}_{1/2}; 2, 1$	254.0138700 <sup>p</sup> 5	
$^{42}_{19}\text{K}$	12h	2	-1.138 <sup>a</sup> 5		53B19	$^2\text{S}_{1/2}; ^5/2, ^3/2$	1258.9 1	
$^{42}_{19}\text{K}$	12h		-1.141 <sup>d</sup> 3		64Kh01	$^2\text{S}_{1/2}; ^5/2, ^3/2$	1258.877 4	
$^{42}_{19}\text{K}$	12h		$\pm 1.1424^{k, d} 8$		69Ch20 73Co36	$^2\text{S}_{1/2}; ^5/2, ^3/2$	1258.876947 15	$a=-503.550779\ 5$ $g=3.10672 \times 10^{-4}\ 45$
$^{43}_{19}\text{K}$	22h	3/2	$\pm 0.163^{a, d} 2$		59P26	$^2\text{S}_{1/2}; 2, 1$	192.64 5	
$^{45}_{19}\text{K}$	20m	3/2	$\pm 0.1734^{a, d} 4$		67Ga08 68Ga28	$^2\text{S}_{1/2}; 2, 1$	204.5873 15	$a=102.2936\ 7$
$^{43}_{20}\text{Ca}$			$\pm 1.317\ 3$		59K82	$^1\text{S}_0$		$g/g(^1\text{H})=0.0673$
$^{43}_{21}\text{Sc}$	3.9h	7/2	+4.62 <sup>a</sup> 4	-0.26 6	66Co13	$^2\text{D}_{5/2}$		$a=+105.7\ 9$ $b=-44\ 10$
$^{44}_{21}\text{Sc}$	3.9h	2	+2.56 <sup>a</sup> 3	+0.10 5	66Co13	$^2\text{D}_{5/2}$		$a=+102.5\ 12$ $b=+18\ 8$
$^{44m}_{21}\text{Sc}$	2.4d	6	+3.88 <sup>a</sup> 1	-0.19 2	66Co13	$^2\text{D}_{5/2}$		$a=+51.7\ 2$ $b=-33\ 3$
$^{45}_{21}\text{Sc}$				-0.22 1	59F53	$^2\text{D}_{3/2}; 5, 4$ 4, 3 $^2\text{D}_{5/2}; 6, 5$ 5, 4 4, 3	1328.96 10 1085.772 15 635.003 50 543.841 50 444.652 50	$a=+269.560\ 20$ $b=-26.37\ 10$ $a=+109.034\ 10$ $b=-37.31\ 10$ $c=-3.5\ 35\text{kHz}$
$^{46}_{21}\text{Sc}$	84d	4	+3.03 2	+0.119 6	62Pe21	$^2\text{D}_{3/2}; ^{11}/2, ^9/2$ $^9/2, ^7/2$ $^7/2, ^5/2$ $^2\text{D}_{5/2}; ^{13}/2, ^{11}/2$ $^{11}/2, ^9/2$ $^9/2, ^7/2$ $^7/2, ^5/2$ $^5/2, ^3/2$	838.06 11 674.12 6 517.13 10 405.84 6 336.19 2 270.14 3 207.05 3 146.25 3	$a=+150.576\ 9$ $b=+14.38\ 14$ $a=+60.906\ 4$ $b=+20.41\ 10$
$^{47}_{21}\text{Sc}$	3.4d	7/2	+5.34 <sup>a</sup> 2	-0.22 3	66Co13	$^2\text{D}_{5/2}$		$a=+122.2\ 5$ $b=-38\ 6$
$^{48}_{21}\text{Sc}$	1.8d	6			67Re06	$^2\text{D}_{5/2}$		
$^{45}_{22}\text{Ti}$	3.1h	7/2	$\pm 0.095^{a, d} 2$	$\pm 0.015\ 15$	66Co19	$J=3; ^{13}/2, ^{11}/2$ $^{11}/2, ^9/2$	30.5 3 25.4 3	$a=4.59\ 7$ $b=1.5\ 15$

Table F: Nuclear Moments by Atomic and Molecular Beams — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^{47}_{22}\text{Ti}$				+0.29 $I$	65Ch19	$^3F_2$		$a=-85.7033^j 3$
						$^3F_3$		$b=+25.700^j 3$
						$^3F_4$		$a=-52.9047^j 7$
$^{49}_{22}\text{Ti}$				+0.24 $I$	65Ch19	$^3F_2$		$b=+28.082^j 9$
						$^3F_3$		$a=-37.9918^j 6$
						$^3F_4$		$b=+37.681^j 10$
$^{47}_{23}\text{V}$	31m 16d	3/2 4		-0.052 $I$	67Re06 66Re06 67Ch10	$^4F_{9/2}, ^6D$		$a=-85.7261^j 3$
						$^4F_{9/2}, ^4F_{7/2}$		$b=+21.070^j 3$
						$^4F_{9/2}$		$a=-52.9183^j 5$
						$^4F_{7/2}$		$b=+23.030^j 10$
						$^4F_{5/2}$		$a=-38.0042^j 5$
						$^4F_{3/2}$		$b=+30.842^j 13$
						$^6D_{9/2}$		$Q^{49}/Q^{47}=+0.819 1$
						$^6D_{7/2}$		
						$^6D_{5/2}$		
						$^6D_{3/2}$		
$^{49}_{24}\text{Cr}$	42m	5/2	$\pm 0.476^* 3$		70Jo27	$^7S_3; ^{11/2}, ^9/2$	273.657 20	$a=49.754 2$
						$^9/2, ^7/2$	223.893 9	$b=0.018 17$
$^{51}_{24}\text{Cr}$	28d	7/2	$\pm 0.934^* 5$		59C24	$^7/2, ^5/2$	174.134 12	$b/a > 0$
						$^7S_3$		
$^{53}_{24}\text{Cr}$					63Ch17	$^7S_3; ^9/2, ^7/2$	371.691 11	$a=82.5985 15$
						$^7/2, ^5/2$	289.095 7	$b=0.003 8$
$^{53}_{24}\text{Cr}$					64Pe11	$^5/2, ^3/2$	206.499 7	$b/a < 0$
						$^7S_3$		$a=-82.5994 16$
								$b=+0.008 12$

Table F: Nuclear Moments by Atomic and Molecular Beams — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^{51}_{25}\text{Mn}$	45m	5/2	$\pm 3.56^*$		68Jo19	$^6\text{S}_{5/2}$		$a=74.835\ 2$ $b=0.024\ 7$
$^{52}_{25}\text{Mn}$	5.7d	6	$\pm 3.058^* 1$		66Ad03	$^6\text{S}_{5/2} + \text{admixtures}$		$a=26.759\ 3$ $ b <0.100$
$^{52m}_{25}\text{Mn}$	21m	2	$\pm 0.0076^* 4$		65Ph04	$^6\text{S}_{5/2}$		$a=\pm 0.200\ 4$
$^{52m}_{25}\text{Mn}$	21m	2	$\pm 0.0076^* 3$		65Sa22	$^6\text{S}_{5/2}$		$a=0.200\ 3$
$^{55}_{25}\text{Mn}$					57W46	$^6\text{S}_{5/2}$		
$^{55}_{25}\text{Mn}$					65Ev07	$^6\text{S}_{5/2}$		
$^{56}_{25}\text{Mn}$	2.6h	3	$+3.223^* 2$		61Ch05	$^6\text{S}_{5/2}; ^{11/2}, ^9/2$ $^{9/2}, ^7/2$ $^{7/2}, ^5/2$	310.173 15 253.766 10 197.375 8	$a=56.3924\ 23$ $b\leq 0.050$
$^{57}_{26}\text{Fe}$					66Ch16	$^5\text{D}_4$ $^5\text{D}_3$ $^5\text{D}_2$ $^5\text{D}_1$ $^5\text{D}_4$		$a=+38.0795\ 10$ $a=+26.351\ 2$ $a=+18.762\ 2$ $a=+14.077\ 5$
$^{59}_{26}\text{Fe}$	45d	3/2			65Doll			
$^{59}_{27}\text{Co}$			$\pm 0.404\ 40$		61Eh01	$^4\text{F}_{9/2}; 8, 7$ 7, 6 6, 5 5, 4 4, 3	3655.470 200 3169.440 50 2695.056 100 2230.638 50 1774.548 50	$a=450.284\ 10$ $b=139.63\ 50$
$^{59}_{27}\text{Co}$					65Ch19	$^4\text{F}_{7/2}$		$a=+490.5779^j 8$ $b=+95.153^j 16$
$^{59}_{27}\text{Co}$			$+4.64\ 21$	$+0.380$	68Ch09	$^4\text{F}_{9/2}; (3\text{d}^7\text{4s}^2)$		$a=+613.3762^j 8$ $b=+68.255^j 14$
						$^4\text{F}_{7/2}$		$a=450.283\ 1$ $b=139.230\ 30$ $c=0.000\ 3$
						$^4\text{F}_{5/2}$		$a=490.567\ 2$ $b=94.501\ 36$ $c=0.000\ 4$
						$^4\text{F}_{3/2}$		$a=613.349\ 3$ $b=67.541\ 50$ $c=-0.002\ 3$
				$+0.345$		$^4\text{F}_{9/2}; (3\text{d}^8\text{4s})$		$a=1042.981\ 1$ $b=67.618\ 2$ $a=828.799\ 4$ $b=-118.8\ 3$ $c=0.002\ 4$
						$^4\text{F}_{7/2}$		$a=668.919\ 1$ $b=-79.2\ 2$ $c=0.004\ 4$
						$^4\text{F}_{5/2}$		$a=562.183\ 3$ $b=-54.8\ 3$
$^{60m}_{27}\text{Co}$	10.5m	2		$+0.36^{\pm} 7$	68Ro08			$\ddagger$ Average value
$^{60m}_{27}\text{Co}$	10.5m	2	$+4.40^{\pm} 9$	$+0.3^{\pm} 4$	69Hu12			

Table F: Nuclear Moments by Atomic and Molecular Beams — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^{61}_{28}\text{Ni}$				+0.126	68Ch10	$^3\text{F}_4:(3\text{d}^84\text{s}^2)$		$a=-215.040\ 2$ $b=-56.868\ 18$ $c=0.000\ 1$ $a=-299.311\ 2$ $b=-42.063\ 13$ $a=-454.972\ 3$ $b=-102.951\ 16$ $c=0.000\ 1$ $a=-171.584\ 7$ $b=-56.347\ 23$
				+0.130		$^3\text{F}_3$		
				+0.16*‡ 2		$^3\text{D}_3:(3\text{d}^94\text{s})$		
						$^3\text{D}_2$		
							‡Average value	
$^{60}_{29}\text{Cu}$	24m	2			58R10			
$^{60}_{29}\text{Cu}$	24m		+1.219* 3		68Ph01	$^2\text{S}_{1/2}; ^5/2, ^3/2$	6033 4	$a=2413.1\ 16$
$^{61}_{29}\text{Cu}$	3.3h	3/2			57N09			
$^{61}_{29}\text{Cu}$	3.3h	3/2			58R10			
$^{61}_{29}\text{Cu}$	3.3h		+2.13* 4		66Do01	$^2\text{S}_{1/2}; 2, 1$	11225 200	
$^{62}_{29}\text{Cu}$	9.9m	1			66Do01	$^2\text{S}_{1/2}$		
$^{62}_{29}\text{Cu}$	9.9m		-0.380* 4		68Ph01	$^2\text{S}_{1/2}; ^3/2, ^1/2$	2257.2 5	$a=-1504.8\ 3$
$^{63}_{29}\text{Cu}$					57T12	$^2\text{S}_{1/2}; 2, 1$	11733.83 1	
$^{63}_{29}\text{Cu}$			+2.2228 4		67Fi11	$^2\text{S}_{1/2}; 2, 1$	11733.817412 40	
$^{63}_{29}\text{Cu}$					69Bl08	$^4\text{P}_{5/2}$		$a=2031.239\ 1$ $b=78.993\ 4$ $c=-100\ 180\text{Hz}$ $a=1323.891\ 1$ $b=137.874\ 5$ $c=-340\ 350\text{Hz}$ $g^{63}/g^{65}=0.933524\ 5$
						$^4\text{F}_{9/2}$		
$^{64}_{29}\text{Cu}$	13h	1	$\pm 0.216^* 4$		54L40	$^2\text{S}_{1/2}; ^3/2, ^1/2$	1278 20	
$^{64}_{29}\text{Cu}$	13h		-0.216* 2		66Do01	$^2\text{S}_{1/2}; ^3/2, ^1/2$	1282.140 8	
$^{65}_{29}\text{Cu}$					57T12	$^2\text{S}_{1/2}; 2, 1$	12568.81 1	
$^{65}_{29}\text{Cu}$			+2.3812 4		67Fi11	$^2\text{S}_{1/2}; 2, 1$	12568.779943 120	
$^{65}_{29}\text{Cu}$					69Bl08	$^4\text{P}_{5/2}$		$a=2175.811\ 2$ $b=73.111\ 9$ $c=-10\ 32\text{Hz}$ $a=1418.123\ 2$ $b=127.586\ 19$
						$^4\text{F}_{9/2}$		
$^{66}_{29}\text{Cu}$	5.2m	1	$\pm 0.283^* 5$		64Ro04	$^2\text{S}_{1/2}; ^3/2, ^1/2$	1670 15	
$^{66}_{29}\text{Cu}$	5.2m	1	-0.281* 2		69Cu09	$^2\text{S}_{1/2}$		$a=1112.525\ 4$
$^{67}_{30}\text{Zn}$				+0.16	62Lu04	$^3\text{P}_2; ^9/2, ^7/2$ $^7/2, ^5/2$ $^5/2, ^3/2$ $^3/2, ^1/2$	2418.111 25 1855.690 15 1312.065 15 781.865 15	
$^{67}_{31}\text{Ga}$	9.5h	0*	<0.00004, if $I=1$		57W35	$^2\text{P}_{1/2}$		
$^{67}_{31}\text{Ga}$	78h	3/2			57H86			
$^{67}_{31}\text{Ga}$	78h		+1.8488 4	+0.22	68Eh02	$^2\text{P}_{1/2}; 2, 1$ $^2\text{P}_{3/2}$	2457.72726 90	$a=1228.86582\ 45$ $g=6.705 \times 10^{-4}\ 13$ $a=175.09736\ 15$ $b=71.95750\ 55$
$^{68}_{31}\text{Ga}$	68m	1			58H114	$^2\text{P}_{1/2}; ^3/2, ^1/2$	17.574 15	$a=11.716\ 10$
$^{68}_{31}\text{Ga}$	68m		$\pm 0.01175^* 6$	$\pm 0.0313\ 16$	62Eh02	$^2\text{P}_{3/2}; ^5/2, ^3/2$ $^3/2, ^1/2$	8.695 33 25.611 41	$(a=1.660^* 10)$ $b=10.276\ 17$

Table F: Nuclear Moments by Atomic and Molecular Beams – Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^{69}_{31}\text{Ga}$			+1.999 $\pm$ 5	+0.186	48B17	$^2\text{P}_{1/2}; 2, 1$ $^2\text{P}_{3/2}; 3, 2$ 2, 1 1, 0	2677.56 10 634.890 20 319.062 10 128.274 10	$g=7.239 \times 10^{-4} 15$ $a=190.790 5$ $b=62.518 12$ $c < 100\text{Hz}$
$^{69}_{31}\text{Ga}$							‡ Determined from $\Delta m=\pm 1$ doublet separation for $J=3/2$ state.	
$^{69}_{31}\text{Ga}$							Value subject to error due to perturbation effects of nearby states	
$^{69}_{31}\text{Ga}$								
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$^{69}_{31}\text{Ga}$								
$^{69}_{31}\text{Ga}$								
$^{70}_{31}\text{Ga}$	21m	1	+2.547 $\pm$ 5	+0.117	62Eh01 48B17	$^2\text{P}_{1/2}$ $^2\text{P}_{1/2}; 2, 1$ $^2\text{P}_{3/2}; 3, 2$ 2, 1 1, 0	3402.09 20 766.673 20 455.450 10 203.028 10 $\eta=1.0886 290$	$g=9.218 \times 10^{-4} 15$ $a=242.424 5$ $b=39.398 10$ $c < 100\text{Hz}$ $a'''=-107.76 98$
$^{71}_{31}\text{Ga}$							‡ Determined from $\Delta m=\pm 1$ doublet separation for $J=3/2$ state.	
$^{71}_{31}\text{Ga}$							Value subject to error due to perturbation effects of nearby states	
$^{71}_{31}\text{Ga}$								
$^{71}_{31}\text{Ga}$								
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$^{71}_{31}\text{Ga}$								
$^{71}_{31}\text{Ga}$								
$^{71}_{31}\text{Ga}$								
$^{71}_{31}\text{Ga}$								
$^{71}_{31}\text{Ga}$								
$^{72}_{31}\text{Ga}$	14h	3	-0.13210 $\pm$ 5	+0.58 1	60Ch13	$^2\text{P}_{1/2}; ^7/2, ^5/2$ $^2\text{P}_{3/2}; ^9/2, ^7/2$ 7/2, 5/2	153.653 1 117.103 3 89.700 15	$a=-43.9009 3$ $a=-6.2593 27$ $b=+193.693 16$
$^{72}_{31}\text{Ga}$								
$^{72}_{31}\text{Ga}$								
$^{72}_{31}\text{Ga}$								
$^{69}_{32}\text{Ge}$	38h	5/2	$\pm 0.735^* 7$	$\pm 0.028 6$	70Ol02	$^3\text{P}_1$		$a=23.40 3$ $b=8.28 8$
$^{71}_{32}\text{Ge}$	11d	1/2	$\mu/Q$ positive		63Ch12	$^3\text{P}_1; ^3/2, ^1/2$ $^3\text{P}_2; ^5/2, ^3/2$		$a=87.005 3$ $a=357 6$
$^{71}_{32}\text{Ge}$	11d		+0.65 20		66Ch02	$^3\text{P}_1$		$(a=87.005 3)$
$^{71}_{32}\text{Ge}$	11d		$\pm 0.546^* 5$		70Ol02	$^3\text{P}_2$		$a=+360.53 6$

Table F: Nuclear Moments by Atomic and Molecular Beams — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^{73}_{32}\text{Ge}$				-0.18 $\pm$ 3	66Ch02	$^3\text{P}_1$		$a=+15.5480 \ 18$ $b=-54.566 \ 9$ $a=-64.4270 \ 7$ $b=+111.825 \ 13$
						$^3\text{P}_2$		
$^{73}_{32}\text{Ge}$ $^{75}_{32}\text{Ge}$	82m	1/2	+0.509 $\pm$ 5	-0.173 $\pm$ 26	70Ol02	$^3\text{P}_1$		$\ddagger$ Average value
					70Ol02	$^3\text{P}_2$		
$^{70}_{33}\text{As}$ $^{72}_{33}\text{As}$ $^{75}_{33}\text{As}$	55m 26h	4 2	$\pm 2.2^{*\text{pp}}$		69Ph04			$a=-66.204 \ 1$ $b=-0.535 \ 3$
					69Ph04			
$^{76}_{33}\text{As}$	26h	2		$\pm 7.8$	61Ch10	$^4\text{S}_{3/2}$		$a=30.5 \ 35$ $b=12.14$
						$^4\text{S}_{3/2}; ^7/2, ^5/2$ $^5/2, ^3/2$	117 4 69 16	
$^{76}_{35}\text{Br}$	17h	1	$\pm 0.5479^*\ 1$ $\mu/Q$ negative	$\pm 0.26 \ 1$	60Li11	$^2\text{P}_{3/2}; ^5/2, ^3/2$ $^3/2, ^1/2$	1256.47 5 189.11 5	$a=345.422 \ 14$ $b=314.329 \ 22$
$^{77}_{35}\text{Br}$ $^{79}_{35}\text{Br}$ $^{79}_{35}\text{Br}$ $^{79}_{35}\text{Br}$	58h	3/2	$\pm 2.110 \ 21$ positive	$+0.32 \ 2$	59G92			$\text{CsBr}, \text{LiBr}$ $^{39}\text{KBr}$
					47B24			
$^{79}_{35}\text{Br}$		3/2		$+0.32 \ 2$	53F33			$Q^{79}/Q^{81}=1.1973^{\text{E}} \ 6$ $a=884.810 \ 3$ $b=-384.878 \ 8$
					54K11	$^2\text{P}_{3/2}; 3, 2$ 2, 1 1, 0	2269.552 2154.499 1269.702	
$^{79}_{35}\text{Br}$				$+0.293^c$	62Ko22 (54K11)			$c \leq 0.0001$
$^{79}_{35}\text{Br}$			$\Omega=+0.116$		66Br03	$^2\text{P}_{3/2}; 3, 2$ 2, 1 1, 0	2269.55564 10 2154.49879 10 1269.70100 50	$a=884.80977 \ 6$ $b=-384.88284 \ 20$ $c=388 \ 8\text{Hz}$
$^{79}_{35}\text{Br}$ $^{79}_{35}\text{Br}$			$\Omega=+0.123^c$ $\Omega=+0.0928^*\text{e}$	$+0.445^c$ $+0.367^*\text{e}$	69He04			$Q^{79}/Q^{81}=1.197056 \ 6$ $a=884.809720^c$ $b=-384.882900^c$ $c=393^*\text{Hz}$
					71Am02	$^2\text{P}_{3/2}$		
$^{80}_{35}\text{Br}$ $^{80}_{35}\text{Br}$	18m	1	$\pm 0.5138^*\ 6$ $\mu/Q$ positive	$\pm 0.18 \ 8$ $\pm 0.19^*$	59L41	$^2\text{P}_{3/2}; ^5/2, ^3/2$ $^3/2, ^1/2$	525.2 12 998.0 10	$a=323.9 \ 4$ $b=227.62 \ 10$
					64Wh05			
$^{80m}_{35}\text{Br}$ $^{80m}_{35}\text{Br}$	4.5h	5	$+1.3170 \ 6$	$+0.71 \ 3$ $+0.74^*$	59L41	$^2\text{P}_{3/2}; ^{13}/2, ^{11}/2$ $^{11}/2, ^9/2$	510.62 25 1277.80 18	$a=+166.05 \ 2$ $b=-874.9 \ 2$
					64Wh05			
$^{81}_{35}\text{Br}$ $^{81}_{35}\text{Br}$		3/2	$\pm 2.271 \ 23$ positive	$+0.27 \ 2$	47B24			$\text{CsBr}, \text{LiBr}$ $a=953.770 \ 3$ $b=-321.516 \ 8$
					54K11	$^2\text{P}_{3/2}; 3, 2$ 2, 1 1, 0	2539.794 2229.056 1275.271	
$^{81}_{35}\text{Br}$			$\Omega=+0.129$		66Br03	$^2\text{P}_{3/2}; 3, 2$ 2, 1 1, 0	2539.79156 10 2229.05377 10 1275.30352 50	$a=953.76818 \ 6$ $b=-321.52428 \ 20$ $c=430 \ 8\text{Hz}$
$^{82}_{35}\text{Br}$	36h	5	$\pm 1.6264^*\ 5$ $\mu/Q$ positive	$\pm 0.73 \ 3$	59G12	$^2\text{P}_{3/2}; ^{13}/2, ^{11}/2$ $^{11}/2, ^9/2$ $^9/2, ^7/2$	766.82 60 1287.32 43 1488.6 11	$a=205.04 \ 5$ $b=870.7 \ 9$ $b/a=-4.246 \ 1$
$^{83}_{36}\text{Kr}$ $^{83}_{36}\text{Kr}$	9/2?	9/2	-0.971	$+0.251 \ 5$	46K05	$^3\text{P}_2; ^{13}/2, ^{11}/2$ $^{11}/2, ^9/2$	1830.714 10	$a=-243.970 \ 4$ $b=-452.12 \ 8$ $(c \approx -2 \ 2\text{kHz assumed})$
					61Ku07		1341.820 20	

Table F: Nuclear Moments by Atomic and Molecular Beams — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^{83}_{36}\text{Kr}$			$\Omega = -0.18$ 6	+0.270 13	63Fa01	$^3\text{P}_2: ^{13}/_2, ^{11}/_2$ $^{11}/_2, ^9/_2$ $^9/_2, ^7/_2$ $^7/_2, ^5/_2$	1830.7236 5 1341.8217 2 956.5583 2 656.0844 30	$a = -243.9693$ 1 $b = -452.1697$ 36 $c = -0.00080$ 20
$^{85}_{36}\text{Kr}$	11y		$\pm 1.005$	+0.42 4	61Ku07 (55R13)			$(\mu^{85}/\mu^{83} = 1.035$ 2) $(Q^{85}/Q^{83} = 1.66$ 10)
$^{81}_{37}\text{Rb}$	4.7h	3/2			56H52			
$^{81}_{37}\text{Rb}$	4.7h		+2.05 <sup>a</sup> 2		57H75	$^2\text{S}_{1/2}: 2, 1$	5097 13	
$^{81}_{37}\text{Rb}$	4.7h		+2.42 <sup>d</sup> 44		62Fa04	$^2\text{S}_{1/2}: 2, 1$	5111.589 40	
$^{81m}_{37}\text{Rb}$	32m	9/2			56H69			
$^{82m}_{37}\text{Rb}$	6.3h	5			56H52			
$^{82m}_{37}\text{Rb}$	6.3h		+1.50 <sup>a</sup> 2		57H75	$^2\text{S}_{1/2}: ^{11}/_2, ^9/_2$	3094.1 24	
$^{82m}_{37}\text{Rb}$	6.3h				62Fa04	$^2\text{S}_{1/2}: ^{11}/_2, ^9/_2$	3094.084 6	
$^{82m}_{37}\text{Rb}$	6.3h		$\pm 1.6427$ 12		68Co18	$^2\text{S}_{1/2}: ^{11}/_2, ^9/_2$	3094.08265 30	
$^{83}_{37}\text{Rb}$	83d	5/2			56H52			
$^{83}_{37}\text{Rb}$	83d		+1.42 <sup>a</sup> 2		57H75	$^2\text{S}_{1/2}: (3.2)$	3183.3 58	
$^{84}_{37}\text{Rb}$	33d	2			56H52			
$^{84}_{37}\text{Rb}$	33d		-1.32 <sup>a</sup> 2		57H75	$^2\text{S}_{1/2}: ^5/_2, ^3/_2$	3077.5 51	
$^{84}_{37}\text{Rb}$	33d				62Kh03	$^2\text{S}_{1/2}: ^5/_2, ^3/_2$	3083.159 4	
$^{85}_{37}\text{Rb}$		5/2 <sup>b</sup>			36M01			
$^{85}_{37}\text{Rb}$			+1.346 5		39K07		$\text{Rb}_2$	$g/g(^7\text{Li}) = 0.247$ 1
$^{85}_{37}\text{Rb}$					54T35		$^{85}\text{Rb}^{35}\text{Cl}$	$Q^{85}/Q^{87} = 2.0669^{\text{E}} 5$
$^{85}_{37}\text{Rb}$				$\pm 0.27$ 2	56S59	$^2\text{P}_{3/2}: 4, 3$ 3, 2	120.8 65.0	$a = 25.3$ 2 $b = 24.4$ 13
$^{85}_{37}\text{Rb}$						$^2\text{P}_{1/2}: 3, 2$	362 3	$a = 120.7$ 10
$^{85}_{37}\text{Rb}$				$\pm 0.30^{\text{c}}$	62Ko22 (56S59)			
$^{85}_{37}\text{Rb}$					62Pe14	$^2\text{S}_{1/2}: 3, 2$	3035.732439 5	
$^{85}_{37}\text{Rb}$					64Bo07		$^{85}\text{RbF}$	$eqQ = -70.3406^{\text{E}} 10$
$^{85}_{37}\text{Rb}$					67Bo40		$\text{RbF}$	$Q^{85}/Q^{87} = +2.06694$ 6
$^{85}_{37}\text{Rb}$			$\pm 1.3521$ 10		67Gr08		$^{85}\text{RbF}$	
$^{85}_{37}\text{Rb}$			+1.3524 <sup>b</sup> 2		68Eh01			$g \neq g \bar{f}$ $-1.466478 \times 10^{-4}$ 22
$^{85}_{37}\text{Rb}$					69De33			$g \neq g \bar{f}$ $-1.466477 \times 10^{-4}$ 34
$^{86}_{37}\text{Rb}$	19d	2	-1.70 <sup>a</sup> 1		53B19	$^2\text{S}_{1/2}: ^5/_2, ^3/_2$	3960 20	
$^{86}_{37}\text{Rb}$	19d		-1.6912 <sup>d</sup> 5		61Br16	$^2\text{S}_{1/2}: ^5/_2, ^3/_2$	3946.883 2	$g = 4.590 \times 10^{-4}$ 4
$^{87}_{37}\text{Rb}$	47Gy	3/2 <sup>b</sup>			36M01			
$^{87}_{37}\text{Rb}$	47Gy		+2.744 9		39K07		$\text{Rb}_2$	$g/g(^7\text{Li}) = 0.8399$ 28
$^{87}_{37}\text{Rb}$	47Gy			$\pm 0.13$ 1	56S59	$^2\text{P}_{3/2}: 3, 2$	265 3	$a = 85.8$ 7 $b = 11.8$ 6 $a = 409$ 4
$^{87}_{37}\text{Rb}$	47Gy					$^2\text{P}_{1/2}$		
$^{87}_{37}\text{Rb}$					61Es03	$^2\text{S}_{1/2}: 2, 1$	6834.682614 1	
$^{87}_{37}\text{Rb}$					62Pe14	$^2\text{S}_{1/2}: 2, 1$	6834.682614 3	
$^{87}_{37}\text{Rb}$			+2.74996 <sup>d</sup> 20		67Fill			
$^{87}_{37}\text{Rb}$					68Du05	$^5\text{P}_{1/2}: 2, 1$	812 15	
$^{88}_{37}\text{Rb}$	18m	2	$\pm 0.508^{\text{a}}$ 5		68Va03	$^2\text{S}_{1/2}: ^5/_2, ^3/_2$	1186.084 18	
$^{87}_{38}\text{Sr}$			-1.0924 9		59K82		Sr metal	
$^{89}_{39}\text{Y}$					59F58	$^2\text{D}_{3/2}: 2, 1$ $^2\text{D}_{5/2}: 3, 2$	114.72 20 88.63 60	$a = -57.217$ 15 $a = -28.749$ 30
$^{90}_{39}\text{Y}$				-0.15 <sup>c</sup>	62Ko22			

Table F: Nuclear Moments by Atomic and Molecular Beams - Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^{90}_{39}\text{Y}$	64h	2	-1.629 <sup>a</sup> 8	-0.155 3	62Pe01	$^2\text{D}_{5/2}: ^9/2, ^7/2$ $^7/2, ^5/2$ $^5/2, ^3/2$ $^3/2, ^1/2$ $^2\text{D}_{3/2}: ^7/2, ^5/2$ $^5/2, ^3/2$ $^3/2, ^1/2$	403.719 37 293.203 22 198.287 24 114.515 19 613.023 34 410.871 24 235.722 26	$a=-85.258 6$ $b=29.716 38$ $a=-169.749 7$ $b=-21.602 27$
$^{91}_{39}\text{Y}$	58d	1/2	$\pm 0.1640^a 8$		62Pe21	$^2\text{D}_{3/2}: 2, 1$ $^2\text{D}_{5/2}: 3, 2$	136.69 3 103.05 4	$a=68.34 2$ $a=34.35 3$
$^{103}_{45}\text{Rh}$					68Ch16	$^4\text{F}_{9/2}$ $^4\text{F}_{7/2}$ $^4\text{F}_{5/2}$ $^4\text{F}_{3/2}$ $^2\text{F}_{7/2}$ $^2\text{F}_{5/2}$ $^2\text{D}_{5/2}$ $^2\text{D}_{3/2}$		$a=175.574 1$ $a=87.416 1$ $a=107.385 2$ $a=32.377 1$ $a=88.198 1$ $a=210.88 32$ $a=87.364 2$ $a=91.718 1$
$^{105}_{46}\text{Pd}$				+0.8 1	65Ch19	$^3\text{D}_3$ $^3\text{D}_2$ $^1\text{D}_2$		$a=-391.178^j 1$ $b=-652.906^j 15$ $a=+66.359^j 1$ $b=-398.192^j 10$ $a=621^j 5$ $b=490^j 30$
$^{101}_{47}\text{Ag}$	9m	9/2			70Wa35			
$^{102}_{47}\text{Ag}$	13m	5			70Wa35			
$^{102m}_{47}\text{Ag}$	7m	2			68Gr01			
$^{102m}_{47}\text{Ag}$	7m		+4.2 <sup>pp</sup> 2		71Cr60	$^2\text{S}_{1/2}: ^5/2, ^3/2$	39400 <sup>p</sup> 1800	
$^{103}_{47}\text{Ag}$	66m	7/2			58E85	$^2\text{S}_{1/2}: 4, 3$	39700 500	$a=9925 125$
$^{103}_{47}\text{Ag}$	66m		+4.45 <sup>d</sup> 5		70Wa35	$^2\text{S}_{1/2}: 11/2, 9/2$	33500 <sup>+2000</sup> <sub>-1000</sub>	
$^{104}_{47}\text{Ag}$	1.2h	5			59E89	$^2\text{S}_{1/2}$		
$^{104}_{47}\text{Ag}$	1.2h	5	+4.0 <sup>pp</sup> 2		61Am02	$^2\text{S}_{1/2}: 11/2, 9/2$	33500 <sup>+2000</sup> <sub>-1000</sub>	
$^{104m}_{47}\text{Ag}$	27m	2			58R10	$^2\text{S}_{1/2}$		
$^{104m}_{47}\text{Ag}$	27m	2			59E89	$^2\text{S}_{1/2}$		
$^{105}_{47}\text{Ag}$	27m	2	+3.7 <sup>a</sup> 2		61Am02	$^2\text{S}_{1/2}: ^5/2, ^3/2$	35000 2000	
$^{105}_{47}\text{Ag}$	40d	1/2			58E84			
$^{105}_{47}\text{Ag}$	40d		$\pm 0.1014^a 10$		63Ew02	$^2\text{S}_{1/2}: 1, 0$	1529.057 20	
$^{106}_{47}\text{Ag}$	24m	1			58R10	$^2\text{S}_{1/2}$		
$^{106}_{47}\text{Ag}$	24m	1			59E89	$^2\text{S}_{1/2}$		
$^{106}_{47}\text{Ag}$	24m		positive		61Am02			
$^{106}_{47}\text{Ag}$	24m		large					
$^{106}_{47}\text{Ag}$	24m		+2.88 <sup>a</sup> 14		68Ph02	$^2\text{S}_{1/2}: ^3/2, ^1/2$	32700 1600	
$^{106m}_{47}\text{Ag}$	8.3d	6			59E89	$^2\text{S}_{1/2}$		
$^{107}_{47}\text{Ag}$					53W33	$^2\text{S}_{1/2}: 1, 0$	1712.56 4	
$^{107}_{47}\text{Ag}$					66Bl11	$^2\text{D}_{5/2}: 3, 2$	378.8453 3	$a=-126.2818 1$
$^{107}_{47}\text{Ag}$					67Da04	$^4\text{F}_{9/2}: 5, 4$	1596.7506 6	$a=-319.339 5$
$^{107}_{47}\text{Ag}$					69De33	$^2\text{S}_{1/2}: 1, 0$	1712.512111 18	$g=1.22982 \times 10^{-4} 71$
$^{107}_{47}\text{Ag}$			-0.113431 <sup>b</sup> 70		64Ro04			
$^{108}_{47}\text{Ag}$	2.4m	1			69Cu09	$^2\text{S}_{1/2}$		
$^{108}_{47}\text{Ag}$	2.4m		+2.80 <sup>a</sup> 1		53W33	$^2\text{S}_{1/2}: 1, 0$	1976.94 4	$a=20800 150$
$^{109}_{47}\text{Ag}$					66Bl11	$^2\text{D}_{5/2}: 3, 2$	435.4750 15	$a=-145.1584 5$
$^{109}_{47}\text{Ag}$					67Da04	$^4\text{F}_{9/2}: 5, 4$	1841.1564 9	$a=-368.214 9$
$^{109}_{47}\text{Ag}$						$^2\text{S}_{1/2}: 1, 0$	1976.932075 17	

Table F: Nuclear Moments by Atomic and Molecular Beams - Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^{109m}_{47}\text{Ag}$	40s	7/2			65St18			
$^{109m}_{47}\text{Ag}$	40s		$\pm 4.31^* 4$		66St22			$a=21200 \ 300$
$^{110}_{47}\text{Ag}$	24s	1	$+2.85^* 5$		69Cu09	$^2\text{S}_{1/2}$		
$^{110m}_{47}\text{Ag}$	253d	6			58E84	$^2\text{S}_{1/2}$		
$^{110m}_{47}\text{Ag}$	253d		$+3.604^d 4$		67Sc04	$^3\text{S}_{1/2}; ^{13/2}, ^{11/2}$	30313.756 4	
$^{111}_{47}\text{Ag}$	7.5d	1/2	$\pm 0.144^* 7$		54L40	$^2\text{S}_{1/2}; 1, 0$	2180 100	
$^{111}_{47}\text{Ag}$	7.5d	1/2	$-0.145^* 2$		56W27	$^2\text{S}_{1/2}; 1, 0$	2204.54 5	
$^{112}_{47}\text{Ag}$	3.2h	2	$\pm 0.0548^* 5$		64Ch06	$^2\text{S}_{1/2}; ^5/2, ^3/2$	518.332 18	
$^{113}_{47}\text{Ag}$	5.3h	1/2	$\pm 0.159^* 2$		64Ch06	$^2\text{S}_{1/2}; 1, 0$	2408.065 28	
$^{111}_{48}\text{Cd}$					60Fa08	$^3\text{P}_2; ^5/2, ^3/2$	8232.341 2	
$^{113}_{48}\text{Cd}$					60Fa08	$^3\text{P}_2; ^5/2, ^3/2$	8611.586 4	
$^{109}_{49}\text{In}$	4.3h	9/2	$+5.53^* 6$	+1.20	59M19	$^2\text{P}_{3/2}$		$a=242.38 \ 56$ $b=462.1 \ 64$
$^{110}_{49}\text{In}$	66m	2			67Pr13	$^2\text{P}_{3/2}$		
$^{110}_{49}\text{In}$	66m	2	$+4.360 \ 4$	+0.36 2	68Ca10	$^2\text{P}_{3/2}$		$a=429.20 \ 36$
$^{110m}_{49}\text{In}$	4.9h	7	$+10.4^* 1$	-0.290	68Ca25			$b=192.5 \ 7$
			or					$a=291.4 \ 12$
			-10.7 <sup>a</sup> 1	+0.311		$^2\text{P}_{3/2}$	(for $\mu > 0$ )	$b=-112 \ 16$
							(for $\mu < 0$ )	or $a=-301.4 \ 13$
$^{111}_{49}\text{In}$	2.8d	9/2	$+5.53^* 6$	+1.18	59M19	$^2\text{P}_{3/2}$		$b=120 \ 17$
$^{112}_{49}\text{In}$	14m	1	$+2.81 \ 3$	+0.089 5	68Ca10	$^2\text{P}_{3/2}$		$a=241.78 \ 30$
					68Ca25			$b=455.3 \ 34$
$^{112m}_{49}\text{In}$	21m	4			68Ca14			$a=554 \ 4$
$^{113}_{49}\text{In}$					38M05			$b=48.3 \ 25$
$^{113}_{49}\text{In}$		9/2			50M02	$^2\text{P}_{3/2}$		
				$\pm 1.144$		5, 4	1115.807	$(a=241.624^* 24)$ $b=443.102 \ 44$
$^{113}_{49}\text{In}$					52K10	$^2\text{P}_{3/2}; 6, 5$	1745.4575 5	
$^{113}_{49}\text{In}$					57E07	5, 4	1115.8253 5	$a=241.641293 \ 58$
				$\Omega = \pm 0.574 \ 15$		4, 3	670.9552 5	$b=443.46626 \ 52$
								$c=0.001728 \ 45$
$^{113}_{49}\text{In}$					57E09	$^2\text{P}_{1/2}; 5, 4$	11385.4300 20	
$^{113}_{49}\text{In}$					62Ko22			
					(50M02)			
$^{113m}_{49}\text{In}$	1.7h	1/2	$-0.21050^* 6$		60Ch08	$^2\text{P}_{1/2}; 1, 0$	781.084 10	
$^{114m}_{49}\text{In}$	50d	5	$+4.7^* 1$		57G23	$^2\text{P}_{1/2}; ^{11/2}, ^{9/2}$	9700 200	
$^{115}_{49}\text{In}$	0.6Jy	9/2			38M05			
$^{115}_{49}\text{In}$	0.6Jy	9/2 <sup>b</sup>			39H12	$^2\text{P}_{3/2}; 6, 3$	3552.0 45	$a=243.0 \ 30$
$^{115}_{49}\text{In}$	0.6Jy	9/2	$+5.52 \pm 4$		42H07	$^2\text{P}_{1/2}; 6, 5$	11387 3	$b=458.8 \ 78$
								$\Delta\nu^{115}/\Delta\nu^{113} = 1.00224 \ 10$
								<sup>f</sup> Determined from $\Delta m = \pm 1$ doublet separation for $J=3/2$ state. Value subject to error due to perturbation effects of nearby states
$^{115}_{49}\text{In}$	0.6Jy			$\pm 1.161$	50M02	$^2\text{P}_{3/2}; 6, 5$	1752.702 35	$a=242.165 \ 2$
						5, 4	1117.153 24	$b=449.562 \ 17$
$^{115}_{49}\text{In}$	0.6Jy			$\pm 0.834^c$	52K10	4, 3	668.960 13	

Table F: Nuclear Moments by Atomic and Molecular Beams - Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^{115}_{49}\text{In}$	0.6Jy		$\Omega=\pm 0.565$ 12		57E07	$^2\text{P}_{1/2}; 5, 4$ $^2\text{P}_{3/2}; 6, 5$ 5, 4 4, 3	11409.7474 39 1752.6865 2 1117.1676 2 668.9631 2	$a=242.165057$ 23 $b=449.59656$ 21 $c=0.001702$ 35
$^{115}_{49}\text{In}$	0.6Jy		$\Omega=+0.475$ 11		57E09	$^2\text{P}_{1/2}; 5, 4$	11409.7506 20	$(c=82^j$ 32Hz) $c=1682$ 40Hz
$^{115m}_{49}\text{In}$	4.5h	1/2		-0.24371* 7	61Ki02 62Ca14	$^2\text{P}_{1/2}$ $^2\text{P}_{3/2}$		$a=-903.5$ 11 $a=-95.973$ 10
$^{116m}_{49}\text{In}$	54m	5	+4.21* 8		56N12	$^2\text{P}_{1/2}; ^{11/2}, ^9/2$	8670 170	
$^{116m}_{49}\text{In}$	54m	5	+4.4* 1		57G23	$^2\text{P}_{1/2}; ^{11/2}, ^9/2$	9000 200	
$^{117}_{49}\text{In}$	45m	9/2			63Ca05			
$^{117m}_{49}\text{In}$	1.9h	1/2	-0.25146 3		68Mu04	$^2\text{P}_{1/2}$ $^2\text{P}_{3/2}$		$a=-932.996$ 12 $a=(-)99.005$ 5
$^{113}_{50}\text{Sn}$	118d	1/2	$\pm 0.879$ * 9		69Pr07 65Ch06	$^3\text{P}_1; ^3/2, ^1/2$ $^3\text{P}_1$ $^3\text{P}_2$	728.91 66	$a=485.911$ 25 $a=+507.445$ 4
$^{117}_{50}\text{Sn}$					65Ch06	$^3\text{P}_1$ $^3\text{P}_2$		$a=-1113.770$ 4
$^{119}_{50}\text{Sn}$					65Ch06	$^3\text{P}_1$ $^3\text{P}_2$		$a=+552.608$ 4
$^{121}_{50}\text{Sn}$	27h	3/2	$\pm 0.699$ * 7	$\pm 0.08$ 4	69Pr07	$^3\text{P}_1$		$a=-1212.956$ 3
$^{123m}_{50}\text{Sn}$	40m	3/2	$\mu/Q$ negative		68Ch38			$a=+578.296$ 4
$^{115}_{51}\text{Sb}$	31m	5/2	+3.46* 1	-0.28‡ 7	68Ja05	$^4\text{S}_{3/2}$		$a=-1269.419$ 3
$^{116}_{51}\text{Sb}$	15m	3			68Ga08			$a=128.726$ 8
$^{117}_{51}\text{Sb}$	2.8h	5/2	+2.67* 1	-0.42‡ 8	68Ja05	$^4\text{S}_{3/2}$		$b=32.374$ 12
$^{118m}_{51}\text{Sb}$	3.5m	1	$\pm 2.46$ * 7		68Ja05	$^4\text{S}_{3/2}$	#For $Q^{121}=-0.28$	$a=-307.68$ 19
$^{119}_{51}\text{Sb}$	38h	5/2	+3.45* 1	-0.29‡ 7	68Ja05	$^4\text{S}_{3/2}$		$b=-3.7$ 5
$^{120}_{51}\text{Sb}$	16m	1	$\pm 2.34$ * 22		68Ja05	$^4\text{S}_{3/2}$	#For $Q^{121}=-0.28$	$a=-237.91$ 15
$^{121}_{51}\text{Sb}$				-0.20 3	60Fe07	$^4\text{S}_{3/2}; 4, 3$ 3, 2 2, 1	1199.08 1 819.45 1 595.12 1	$b=-5.5$ 5
$^{122}_{51}\text{Sb}$	2.8d	2	-1.90*	+0.66‡ 4	60Fe08			
$^{123}_{51}\text{Sb}$				-0.36‡ 5	60Fe07	$^4\text{S}_{3/2}; 5, 4$ 4, 3 3, 2	815.60 1 648.46 1 484.02 1	$a=547$ 13 $a=-307.16$ 6 $b=-3.8$ 4
$^{124}_{51}\text{Sb}$	60d	3			60Fe08		#For $Q^{121}=-0.28$	$a=520$ 47 $a=-299.034$ 4
$^{116}_{52}\text{Te}$	2.5h	0*			61Ax04			$b=-3.68$ 2
$^{117}_{52}\text{Te}$	61m	1/2			61Ax04			
$^{119}_{52}\text{Te}$	16h	1/2			61Ax04			
$^{119}_{52}\text{Te}$	16h	1/2			65Ad03	$J=2$		
$^{119m}_{52}\text{Te}$	4.5d	11/2	$\pm 0.25$ 5		61Ax04			$a=425$ 20

Table F: Nuclear Moments by Atomic and Molecular Beams — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^{123}\text{I}_{53}$	13h	5/2			58G18			
$^{124}\text{I}_{53}$	4.0h	2			58G18			
$^{126}\text{I}_{53}$	13d	2			60Ga12			
$^{127}\text{I}_{53}$		5/2		-0.819 $\ddagger$	53K14			
					53J23			
								‡Livingston et al. (53L24) quote the unpublished value of $Q^{127}=0.819\text{b}$ of Jaccarino, King, and Stroke. The subsequent paper by Jaccarino et al. (54J07) does not give a value of $Q$ but does present the interaction constants and a value of $\Omega^{127}$ . In a private communication, Stroke quotes a value of $Q^{127}=0.789\text{b}$ . This was obtained from the interaction constants of 54J07, using the measured $a^{127}$ to obtain $\langle 1/r^3 \rangle$ . It also includes relativistic corrections
$^{127}\text{I}_{53}$			$\Omega=+0.3$		54J07	$^2\text{P}_{3/2}:4,3$ 3,2 2,1	4226.172 15 1965.884 10 737.492 8	$a=827.265\ 3$ $b=1146.356\ 10$ $c=0.00245\ 37$
$^{127}\text{I}_{53}$				-0.69 $^\circ$ 3	55M88			$(c=0.00287^j\ 37)$
$^{127}\text{I}_{53}$			$\Omega=+0.181^\circ\ 47$		57S28			$c=0.00201\ 52$
$^{127}\text{I}_{53}$				-0.789 $^\circ\ddagger$	59St46			‡Livingston et al. (53L24) quote the unpublished value of $Q^{127}=0.819\text{b}$ of Jaccarino, King, and Stroke. The subsequent paper by Jaccarino et al. (54J07) does not give a value of $Q$ but does present the interaction constants and a value of $\Omega^{127}$ . In a private communication, Stroke quotes a value of $Q^{127}=0.789\text{b}$ . This was obtained from the interaction constants of 54J07, using the measured $a^{127}$ to obtain $\langle 1/r^3 \rangle$ . It also includes relativistic corrections
$^{127}\text{I}_{53}$				-0.64 $^\circ$	62Ko22 (54J07)			
$^{127}\text{I}_{53}$			$\Omega=+0.265^\circ$	-1.097 $^\circ$	71Am02	$^2\text{P}_{3/2}$		$a=827.26502^\circ$
			$\Omega=+0.167^\circ\circ$	-0.750 $^\circ\circ$	(54J07)			$b=1146.35920^\circ$
								$c=2602^\circ\text{Hz}$
$^{128}\text{I}_{53}$	25m	1			59S63			
$^{130}\text{I}_{53}$	12h	5			58G20			
$^{130}\text{I}_{53}$	12h	5			59S63			
$^{131}\text{I}_{53}$	8d	7/2			58G18			
$^{131}\text{I}_{53}$	8d	7/2	+2.738 $^\circ\ 1$	-0.40 1 -0.41* 1	60Li13	$^2\text{P}_{3/2}:5,4$ 4,3 3,2	3292.99 9 2138.22 5 1314.24 7	$a=575.903\ 7$ $b=578.866\ 75$
$^{132}\text{I}_{53}$	2.3h	4			59S64			
$^{132}\text{I}_{53}$	2.3h	4			60Ga12			
$^{132}\text{I}_{53}$	2.3h		$\pm 3.08^\circ\ 2$	$\pm 0.075\ 15$	62Wh11	$^2\text{P}_{3/2}$		$a=567.6\ 26$ $b=128.2\ 206$
$^{133}\text{I}_{53}$	21h	7/2	$\mu/Q$ negative		60Ga12			
$^{133}\text{I}_{53}$	21h		+2.836 $^\circ\ 5$	-0.26 1 -0.27* 1	61Al20	$^2\text{P}_{3/2}:5,4$ 4,3 3,2	3260.1 73 2277.9 46 1515.9 61	$a=597.0\ 10$ $b=385.2\ 74$
$^{135}\text{I}_{53}$	6.7h	7/2			60Ga12			
$^{129}\text{Xe}_{54}$			$\Omega=+0.048\ 12$	-0.120 12	61Fa05	$^3\text{P}_2:5/2,3/2$ $^3\text{P}_2:7/2,5/2$ $^5/2,3/2$ $^3/2,1/2$	5961.2577 9 2693.6234 7 1608.3475 8 838.7636 4	$a=+706.4714\ 7$ $b=+252.5145\ 64$ $c=+0.000728\ 105$

Table F: Nuclear Moments by Atomic and Molecular Beams — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^{125}_{55}\text{Cs}$	45m	1/2	+1.41 <sup>a</sup> 2		71Da01	$^2\text{S}_{1/2}:1,0$	8754 40	
$^{127}_{55}\text{Cs}$	6.2h	1/2			56N16			
$^{127}_{55}\text{Cs}$	6.2h		+1.43 <sup>a</sup> 4		58N27	$^2\text{S}_{1/2}:1,0$	8950 200	
$^{127}_{55}\text{Cs}$	6.2h		+1.43 <sup>a</sup> 2		62Kh03	$^2\text{S}_{1/2}:1,0$	8900 150	
$^{127}_{55}\text{Cs}$	6.2h		+1.46 <sup>a</sup> 2		71Da01	$^2\text{S}_{1/2}:1,0$	9109 45	
$^{129}_{55}\text{Cs}$	31h	1/2			56N16			
$^{129}_{55}\text{Cs}$	31h		+1.47 <sup>a</sup> 4		58N27	$^2\text{S}_{1/2}:1,0$	9200 200	
$^{129}_{55}\text{Cs}$	31h		+1.479 <sup>a</sup> 6		62Kh03	$^2\text{S}_{1/2}:1,0$	9229 30	
$^{130}_{55}\text{Cs}$	30m	1			56N16			
$^{130}_{55}\text{Cs}$	30m		+1.37 <sup>a</sup> 8		58N27	$^2\text{S}_{1/2}:{}^3/{}_2, {}^1/{}_2$	6400 350 if $\mu > 0$ or 6800 350 if $\mu < 0$	
$^{131}_{55}\text{Cs}$	10d	5/2	+3.53 <sup>a</sup> 4		53B19	$^2\text{S}_{1/2}:3,2$	13200 110	
$^{131}_{55}\text{Cs}$	10d	5/2			56N14			
$^{131}_{55}\text{Cs}$	10d		+3.537 <sup>d</sup> 2		65Wo05	$^2\text{S}_{1/2}:3,2$	13181.375 2	$g=7.663 \times 10^{-4}$ 4
$^{132}_{55}\text{Cs}$	6.2d	2	+2.22 <sup>a</sup> 2		58N27	$^2\text{S}_{1/2}:{}^5/{}_2, {}^3/{}_2$	8648 35	
$^{133}_{55}\text{Cs}$		7/2			34C04			
$^{133}_{55}\text{Cs}$			+2.574 13		39K10		$\text{Cs}_2, \text{CsF}, \text{CsCl}$	$g/g(^7\text{Li})=0.3369$
$^{133}_{55}\text{Cs}$				-0.0033 39	56Bu19	$^2\text{P}_{3/2}:5,4$ 4,3 3,2	252.5 10 203.0 11 152.0 8	$a=50.67$ 11 $b=-0.46$ 53
$^{133}_{55}\text{Cs}$					58Ma18	$^2\text{S}_{1/2}:4,3$	9192.631770 20	
$^{133}_{55}\text{Cs}$					66En03		$^{133}\text{CsF}$	$eqQ=1.241^{\text{E}}$ 11
$^{134}_{55}\text{Cs}$	2.2y	4	+2.98 <sup>a</sup> 1		67Ma09	$^2\text{P}_{1/2}:4,3$	1167 <sup>E</sup> 40	
$^{134}_{55}\text{Cs}$	2.2y	4	+2.98 <sup>a</sup> 1		52J18	$^2\text{S}_{1/2}:{}^9/{}_2, {}^7/{}_2$	10465 12	
$^{134}_{55}\text{Cs}$	2.2y		+2.9889 <sup>d</sup> $\pm$ 12		53B19	$^2\text{S}_{1/2}:{}^9/{}_2, {}^7/{}_2$	10440 30	
$^{134m}_{55}\text{Cs}$	2.9h	8	+1.10 <sup>a</sup> 1		57S111	$^2\text{S}_{1/2}:{}^9/{}_2, {}^7/{}_2$	10473.626 15	$g/g^{133}=1.01447^{\text{d}}$ 29
$^{134m}_{55}\text{Cs}$	2.9h	8	+1.10 <sup>a</sup> 1					$\pm$ Using $\mu_{\text{unc}}^{133}=2.563189$ 15 (68Ha01)
$^{134m}_{55}\text{Cs}$	2.9h		+1.0960 <sup>d</sup> $\pm$ 3		55G04	$^2\text{S}_{1/2}:{}^{17}/{}_2, {}^{15}/{}_2$	3684.594 20	
$^{134m}_{55}\text{Cs}$	2.9h				55G31	$^2\text{S}_{1/2}:{}^{17}/{}_2, {}^{15}/{}_2$	3684.5 5	
$^{134m}_{55}\text{Cs}$	2.9h				62Co14	$^2\text{S}_{1/2}:{}^{17}/{}_2, {}^{15}/{}_2$	3684.578640 175	
$^{134m}_{55}\text{Cs}$	2.9h				67Ma09	$^2\text{P}_{1/2}:{}^{17}/{}_2, {}^{15}/{}_2$	473 <sup>E</sup> 60	
$^{135}_{55}\text{Cs}$	2My	7/2	+2.728 <sup>a</sup> 2		49D01	$^2\text{S}_{1/2}:4,3$	9724 8	
$^{135}_{55}\text{Cs}$	2My		+2.7280 <sup>d</sup> $\pm$ 8		57S111	$^2\text{S}_{1/2}:4,3$	9724.023 15	$g/g^{133}=1.05820^{\text{d}}$ 8
$^{136}_{55}\text{Cs}$	13d	5	+3.70 <sup>a</sup> 4		71Da01	$^2\text{S}_{1/2}:{}^{11}/{}_2, {}^9/{}_2$	12702 28	
$^{137}_{55}\text{Cs}$	30y	7/2	+2.831 <sup>a</sup> 2		49D01	$^2\text{S}_{1/2}:4,3$	10126.5 70	
$^{137}_{55}\text{Cs}$	30y		+2.8372 <sup>d</sup> $\pm$ 9		57S111	$^2\text{S}_{1/2}:4,3$	10115.527 15	$g/g^{135}=1.04005^{\text{d}}$ 8
$^{138}_{55}\text{Cs}$	32m	3	$\pm$ 0.48 <sup>a</sup> 10		67St22	$^2\text{S}_{1/2}$		$g/g^{133}=2.563189$ 15 (68Ha01)
$^{135}_{56}\text{Ba}$		3/2	+0.836 2		41H14			$a=500$ 100
$^{135}_{56}\text{Ba}$			+0.8370 8		59K82			$g/g(^7\text{Li})=0.2553$ 7
$^{137}_{56}\text{Ba}$		3/2	+0.935 3		41H14			$g/g^{137}=0.8949$ 8
$^{137}_{56}\text{Ba}$			+0.9364 9		59K82			$g/g^{137}=0.8939$ 2
$^{131}_{57}\text{La}$	59m	3/2			73In04			$g/g(^7\text{Li})=0.2856$ 8
$^{132}_{57}\text{La}$	4.5h	2			73In04			
$^{132m}_{57}\text{La}$	25m	6			73In04			
$^{133}_{57}\text{La}$	4.0h	5/2			73In04			
$^{135}_{57}\text{La}$	19.4h	5/2			73In04			
$^{136}_{57}\text{La}$	9.9m	1			73In04			

Table F: Nuclear Moments by Atomic and Molecular Beams - Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^{139}_{57}\text{La}$				+0.230 10	57T30	$^2\text{D}_{5/2}:6,5$ 5,4 4,3 3,2 $^2\text{D}_{3/2}:5,4$ 4,3 3,2	1120.902 5 912.793 5 716.288 3 529.090 10 737.967 15 551.987 5 391.603 10	$a=182.1706\ 6$ $b=54.213\ 14$ $c=-0.6\ 10\text{kHz}$ $a=141.1959\ 16$ $b=44.781\ 14$ $c=0.15\ 44\text{kHz}$
$^{139}_{57}\text{La}$				+0.21 <sup>c</sup> 1	58Mu08 (57T30)			
$^{139}_{57}\text{La}$				+0.229 <sup>c</sup>	62Ko22 (57T30)			
$^{139}_{57}\text{La}$				+0.26, 0.23, or 0.28	71Ch02	$^4\text{F}_{3/2}:5,4$ 4,3 $^4\text{F}_{5/2}:6,5$ 5,4 4,3 $^4\text{F}_{7/2}:7,6$ 6,5 5,4 4,3 $^4\text{F}_{9/2}:8,7$ 7,6 6,5 5,4 4,3 — $^2\text{F}_{5/2}:6,5$ 5,4 4,3 $^2\text{F}_{7/2}:5,4$ 4,3 $^4\text{P}_{1/2}:4,3$ $^4\text{P}_{3/2}:4,3$ — $^4\text{P}_{5/2}:4,3$ — +0.30, 0.31, or 0.28 +0.22*‡ 3	2390.631 11 1925.510 11 1808.938 12 1503.210 18 1199.787 15 3247.744 6 2779.047 7 2312.531 20 1847.837 12 3928.536 27 3430.754 13 2935.669 10 2442.885 22 1952.018 20 1840.665 15 1522.871 15 1211.072 15 989.482 20 796.567 12 9840.632 15 3707.836 22 3216.524 20 <sup>‡</sup> Average value	$a=-480.224\ 8$ $b=14.2\ 2$ $a=300.631\ 8$ $b=14.0\ 3$ $c=0.002\ 3$ $a=462.889\ 7$ $b=19.3\ 2$ $c=-0.002\ 2$ $a=304.381\ 4$ $b=27.8\ 1$ $c=-0.002\ 3$ $a=-197.068\ 7$ $b=41.4\ 2$ $a=2460.173\ 70$ $a=929.6\ 2$ $b=37.2\ 25$ $a=801.9\ 5$ $b=-40\ 8$ $a=-424.9\ 20$ $b=-13\ 4$ $a=881\ 6$ $b=22\ 36$
$^{140}_{57}\text{La}$	40h	3			60Pe09			
$^{140}_{57}\text{La}$	40h		$\pm 0.728^p 15$ $\mu/Q$ positive	$\pm 0.15^* 7$	69Hu12 69Pi15	$^2\text{D}_{5/2}$		$a=55.8^p 15$ $b=40^p 25$
$^{130}_{58}\text{Ce}$	25m	0 <sup>+</sup>			73In04	$^1\text{G}_4; ^3\text{H}_4$		
$^{132}_{58}\text{Ce}$	4.2h	0 <sup>+</sup>			73In04	$^1\text{G}_4; ^3\text{H}_4$		
$^{133}_{58}\text{Ce}$	5.4h	9/2			73In04			
$^{133m}_{58}\text{Ce}$	97m	1/2			73In04			
$^{134}_{58}\text{Ce}$	72h	0 <sup>+</sup>			73In04	$^1\text{G}_4; ^3\text{H}_4$		
$^{135}_{58}\text{Ce}$	17.0h	1/2			73In04			
$^{137}_{58}\text{Ce}$	9.0h	3/2			73In04			
$^{137m}_{58}\text{Ce}$	34.4h	11/2			73In04			
$^{139}_{58}\text{Ce}$	140d	3/2			73In04			
$^{143}_{58}\text{Ce}$	33h	3/2			65Ma19			

Table F: Nuclear Moments by Atomic and Molecular Beams — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^{133}_{59}\text{Pr}$	7.5m	5/2			72Ek04			
$^{134}_{59}\text{Pr}$	18.5m	2			72Ek04			
$^{135}_{59}\text{Pr}$	24m	3/2			72Ek04			
$^{136}_{59}\text{Pr}$	13.5m	2			72Ek04			
$^{137}_{59}\text{Pr}$	1.28h	5/2			72Ek04			
$^{138}_{59}\text{Pr}$	2.0h	7			72Ek04			
$^{139}_{59}\text{Pr}$	4.5h	5/2			72Ek04			
$^{140}_{59}\text{Pr}$	3.4m	1			72Ek04			
$^{141}_{59}\text{Pr}$			+3.8 4	-0.054	53L22	$^4\text{I}_{9/2}; 4, 3$ 3, 2	3708.05 5 2782.25 5	$a=+926.03 \text{ 10}$ $b=-13.9 \text{ 10}$
$^{141}_{59}\text{Pr}$			$\pm 5.09^\circ 25$	-0.02*	58Mu08			
$^{141}_{59}\text{Pr}$			$\mu/Q$ negative	$\pm 0.070^\circ 4$	62Ca10			
$^{141}_{59}\text{Pr}$			+4.98	-0.074	62Wy04			$a=926.2087 \text{ 1}$
$^{141}_{59}\text{Pr}$			+4.28 <sup>c</sup> 8	-0.0589 <sup>c</sup> 42	63Bl25			$b=-11.878 \text{ 2}$
$^{141}_{59}\text{Pr}$			+4.162 <sup>kp</sup> 2		70Le26	$^4\text{I}_{9/2}$		$c=220.80\text{Hz}$
			+4.43 <sup>kp</sup> 11					$a=730.3929 \text{ 1}$
			+4.42 <sup>kp</sup> 12					$b=-11.877 \text{ 3}$
			+4.48 <sup>kp</sup> 5					$c=-0.0003 \text{ 2}$
								$a=613.2399 \text{ 1}$
								$b=-12.850 \text{ 2}$
								$c=-0.0001 \text{ 2}$
								$a=541.5746 \text{ 2}$
								$b=-14.558 \text{ 6}$
								$c=0.0003 \text{ 6}$
$^{142}_{59}\text{Pr}$	19h	2	$\pm 0.243^\ddagger 15$	$\pm 0.035 \text{ 15}$	62Ca10	$^4\text{I}_{9/2}$		$a=67.5 \text{ 5}$
			$\mu/Q$ positive					$b=7.0 \text{ 20}$
$^{142}_{59}\text{Pr}$	19h		$\pm 0.250^\circ$	$\pm 0.0297^\circ 85$	63Bl25			$\dagger$ For $\mu^{141}=4.16$
$^{142m}_{59}\text{Pr}$	?	5 <sup>p</sup>			69Hu12			
$^{143}_{59}\text{Pr}$	14d	7/2			64Bu09	$^4\text{I}_{9/2}$		
$^{134}_{60}\text{Nd}$	8m	0 <sup>+</sup>			72Ek04			
$^{135}_{60}\text{Nd}$	15m	9/2			72Ek04			
$^{136}_{60}\text{Nd}$	55m	0 <sup>+</sup>			72Ek04	$^5\text{I}_4; 5, 4$	<40kHz, if $I=1$	
$^{137}_{60}\text{Nd}$	37m	1/2			72Ek04			
$^{138}_{60}\text{Nd}$	5.2h	0 <sup>+</sup>			72Ek04			
$^{139}_{60}\text{Nd}$	29.7m	3/2			72Ek04			
$^{139m}_{60}\text{Nd}$	5.5h	11/2			72Ek04			
$^{140}_{60}\text{Nd}$	3.4d	0 <sup>+</sup>			72Ek04			
$^{141}_{60}\text{Nd}$	2.5h	3/2			62Al04	$^5\text{I}_4; 11/2, 9/2$	$\geq 1630$	
$^{143}_{60}\text{Nd}$		7/2			62Sp03			
			-1.25 13	-0.57 6	63Sp08	$^5\text{I}_4; 15/2, 13/2$ $13/2, 11/2$ $11/2, 9/2$ $9/2, 7/2$ $7/2, 5/2$	1418.25 14 1257.53 4 1084.70 4 901.47 6 710.0 1	$a=-195.649 \text{ 9}$ $b=+122.25 \text{ 28}$
$^{143}_{60}\text{Nd}$			-1.063 <sup>b</sup> 5	-0.484 <sup>c</sup> 20	65Sm04	$^5\text{I}_4$		$Q^{143}/Q^{145}=+1.893 \text{ 16}$
$^{143}_{60}\text{Nd}$					70Ch41	$^5\text{I}_5$		$g=-1.6430 \times 10^{-4} \text{ 69}$
								$a=-195.652^p \text{ 2}$
								$b=122.608^p \text{ 34}$
								$a=-153.679^p \text{ 2}$
								$b=115.741^p \text{ 36}$
$^{143}_{60}\text{Nd}$	(70Ch41) continued							

Table F: Nuclear Moments by Atomic and Molecular Beams - Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^{143}_{60}\text{Nd}$ (70Ch41) continued						$^5\text{I}_6$		
						$^5\text{I}_7$		$a=-130.611^p 2$ $b=119.284^p 46$
						$^5\text{I}_8$		$a=-117.604^p 2$ $b=129.281^p 48$
$^{145}_{60}\text{Nd}$								$a=-110.4^p 2$
$^{145}_{60}\text{Nd}$								$b=141.9^p 62$
$^{145}_{60}\text{Nd}$	7/2	-0.78 8	-0.30 3	62Sp03	$^5\text{I}_4: ^{15}/_2, ^{13}/_2$ $^{13}/_2, ^{11}/_2$ $^{11}/_2, ^9/_2$ $^9/_2, ^7/_2$ $^7/_2, ^5/_2$	886.25 6		$a=-121.627 27$
$^{145}_{60}\text{Nd}$				63Sp08	$^{11}/_2, ^9/_2$	783.08 4		$b=+64.60 37$
$^{145}_{60}\text{Nd}$						673.49 3		
$^{145}_{60}\text{Nd}$						558.27 3		
$^{145}_{60}\text{Nd}$						439.10 5		
$^{145}_{60}\text{Nd}$						$^5\text{I}_5: ^{17}/_2, ^{15}/_2$ $^{15}/_2, ^{13}/_2$ $^{13}/_2, ^{11}/_2$ $^{11}/_2, ^9/_2$	789.83 20	$a=-95.531 19$
$^{145}_{60}\text{Nd}$						708.38 20		$b=+60.65 70$
$^{145}_{60}\text{Nd}$						622.80 15		
$^{145}_{60}\text{Nd}$						533.36 20		
$^{147}_{60}\text{Nd}$	11d	5/2			65Sm04			$g=-1.0106 \times 10^{-4} 61$
$^{147}_{60}\text{Nd}$	11d		$\pm 0.553^{ap} 10$	$\pm 0.7^p 3$	70Ch41	$^5\text{I}_4$		$a=-121.628^p 2$
$\mu/Q$ negative								$b=64.637^p 28$
$^{149}_{60}\text{Nd}$	1.9h	5/2			64Bu09	$^5\text{I}_5$		$a=-95.535^p 2$
$^{149}_{60}\text{Nd}$	1.9h		$\pm 0.350^{ap} 10$	$\pm 1.0^p 3$	70Pi11	$^5\text{I}_6$		$b=61.044^p 42$
$\mu/Q$ negative								$a=-81.195^p 2$
$^{140m}_{61}\text{Pm}$	5.8m	‡			72Ek05	$^5\text{I}_7$		$b=62.926^p 58$
								$a=-73.108^p 2$
								$b=68.165^p 74$
$^{141}_{61}\text{Pm}$	20.9m	5/2			60Ca03			
$^{147}_{61}\text{Pm}$	2.6y	7/2			70Pi11	$J=4$		$a=144^p 3$
$^{147}_{61}\text{Pm}$	2.6y		$\pm 2.77^c 8$		64Bu09	$^5\text{I}_4$		$b=181^p 64$
$^{147}_{61}\text{Pm}$	2.6y	7/2	$\pm 3.2 3$	$\pm 0.7 3$	70Pi11	$J=4$		
$\mu/Q$ positive								$a=91.0^p 19$
$^{148}_{61}\text{Pm}$	5.4d	1		$+2.07^{ap} 21$	65Al10	$^6\text{H}_{7/2}$		$b=260^p 43$
					65Al16	$^6\text{H}_{7/2}$		
$^{149}_{61}\text{Pm}$	54h	7/2			61Ca07			
$^{151}_{61}\text{Pm}$	28h	5/2			61Ca07			
$^{151}_{61}\text{Pm}$	28h	5/2	$\pm 1.8 2$	$\pm 1.9 3$	63Bu14	$^6\text{H}_{7/2}$		$a=358 22$
$\mu/Q$ positive								$b=778 93$
$^{140}_{62}\text{Sm}$	15m	0 $\ddagger$			72Ek05			
$^{141}_{62}\text{Sm}$	11.3m	1/2			72Ek05			
$^{141m}_{62}\text{Sm}$	22.9m	11/2			72Ek05			
$^{142}_{62}\text{Sm}$	1.2h	0 $\ddagger$			72Ek05	$^7\text{F}$	$<40\text{kHz}$ , if $I=1$	
$^{143}_{62}\text{Sm}$	8.8m	3/2			72Ek05			
$^{147}_{62}\text{Sm}$	0.1Ty	7/2			62Sp03			
$^{147}_{62}\text{Sm}$	0.1Ty		-0.796 <sup>c</sup> 16	-0.208 <sup>c</sup> 4	63Bl25			

Table F: Nuclear Moments by Atomic and Molecular Beams — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^{147}_{62}\text{Sm}$	0.1Ty		-0.8129 7	-0.20 2	66Wo05	$^7F_1$ $^7F_2$ $^7F_3$ $^7F_4$		$a=-33.4936\ I$ $b=-58.6920\ 8$ $a=-41.1845\ 2$ $b=-62.2260\ 32$ $a=-50.2401\ I$ $b=-33.6812\ 16$ $a=-59.7068\ 20$ $b=+21.230\ 72$
$^{147}_{62}\text{Sm}$	0.1Ty				68Ro16	$J=5: ^{17}_2, ^{15}_2$ $^{15}_2, ^{13}_2$ $^{13}_2, ^{11}_2$ $^{11}_2, ^9_2$ $^9_2, ^7_2$	551.009 <sup>j</sup> 42 505.364 <sup>j</sup> 32 452.498 <sup>j</sup> 17 393.414 <sup>j</sup> 11 329.071 <sup>j</sup> 15	$A_1 \dagger = 1209.870\ 23$ $A_2 = 25.1448\ 130$ $A_3 = 0$ $A_1/A_2 < 0$
$^{147}_{62}\text{Sm}$ $^{149}_{62}\text{Sm}$ $^{149}_{62}\text{Sm}$ $^{149}_{62}\text{Sm}$	0.1Ty	7/2	-0.18 <sup>e</sup> 3	69Ro29	$^7F_{1,2,3,4,5}$		‡See 68Ro16 for definitions of $A$ 's	
			-0.643 <sup>e</sup> 15	62Sp03				
			+0.060 <sup>e</sup> 1	63Bl25				
			-0.6702 7	66Wo05	$^7F_1$ $^7F_2$ $^7F_3$ $^7F_4$		$a=-27.6109\ I$ $b=+16.9624\ 4$ $a=-33.9508\ 2$ $b=+17.9872\ 32$ $a=-41.4176\ 4$ $b=+9.7488\ 64$ $a=-49.2177\ 29$ $b=-6.161\ 80$ $Q^{149}/Q^{147} = 0.28901\ 3$	
$^{149}_{62}\text{Sm}$				68Ro16	$J=5: ^{17}_2, ^{15}_2$ $^{15}_2, ^{13}_2$ $^{13}_2, ^{11}_2$	495.031 <sup>j</sup> 27 431.239 <sup>j</sup> 14 369.563 <sup>j</sup> 20	$A_1 \dagger = 997.364\ 38$ $A_2 = 7.258\ 23$ $A_3 = 0$ $A_1/A_2 > 0$	
$^{149}_{62}\text{Sm}$			+0.052 <sup>e</sup> 3	Compilers			‡See 68Ro16 for definitions of $A$ 's ‡Using $Q$ of 69Ro29 and $Q$ -ratio of 66Wo05	
$^{153}_{62}\text{Sm}$ $^{153}_{62}\text{Sm}$	47h	3/2	-0.021 <sup>*</sup> 1	60Ca05	$^7F_1$			
			+1.1 3	64Su02	$^7F_2$ $^7F_3$ $^7F_4$		$a=-2.100\ 5$ $b=+289.042\ 4$ $a=-2.573\ 6$ $b=+306.521\ 21$ $a=-3.115\ 4$ $b=+165.824\ 20$ $a=-3.753\ 9$ $b=-104.452\ 68$	
$^{153}_{62}\text{Sm}$ $^{155}_{62}\text{Sm}$ $^{155}_{62}\text{Sm}$	47h	3/2	-0.0215 1	68Wa10	$^7F$		$Q^{155}/Q^{153} = \pm 0.894$	
$^{145}_{63}\text{Eu}$ $^{146}_{63}\text{Eu}$ $^{147}_{63}\text{Eu}$ $^{148}_{63}\text{Eu}$ $^{149}_{63}\text{Eu}$ $^{150}_{63}\text{Eu}$ $^{151}_{63}\text{Eu}$	5.9d 4.65d 22d 54d 93d 12.5h	5/2 4 5/2 5 5/2 0*	large $\pm 0.9\ I$	72Ek05 72Ek05 72Ek05 72Ek05 72Ek05 60Sa23	$^8S_{7/2}$ $^8S_{7/2}: 6, 5$ 5, 4 4, 3	<40kHz, if $I=1$ 120.675 1 100.286 1 80.049 1	$a=-20.0523\ 2$ $b=-0.7012\ 35$	
$^{151}_{63}\text{Eu}$			+3.4631 <sup>b</sup> 12	65Ev08	$^8S_{7/2}$		$\mu^{151}/\mu^{153} = 2.26505\ 42$ $a^{151}/a^{153} = 2.26498\ 8$	

Table F: Nuclear Moments by Atomic and Molecular Beams — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^{152}_{63}\text{Eu}$	13y		$\pm 1.937\ 2$	$\pm 3.0\ 3$	63Al06	$^8S_{7/2}: ^{13}I_2, ^{11}I_2$ $^{11}I_2, ^9I_2$ $^9I_2, ^7I_2$ $^7I_2, ^5I_2$	59.848 86 51.246 35 42.343 37 33.191 48	$a=9.345\ 6$ $b=1.930\ 165$ $Q^{152}/Q^{151}=\pm 2.75\ 24$ $Q^{152}/Q^{153}=\pm 1.08\ 9$
$^{152m}_{63}\text{Eu}$	9h	0*	$\leq 4 \times 10^{-3}$ , if $I=1$	+2.8 3	59C52	$^8S_{7/2}: 6, 5$ 5, 4 4, 3	54.038 1 44.004 1 35.004 1	$a \leq 60\text{kHz}$ $a=-8.8532\ 2$ $b=-1.7852\ 35$
$^{153}_{63}\text{Eu}$			$+1.5292^b\ 9$		65Ev08	$^8S_{7/2}$		
$^{145}_{64}\text{Gd}$	22.9m	1/2			72Ek05			
$^{147}_{64}\text{Gd}$	38.5h	7/2			72Ek05			
$^{149}_{64}\text{Gd}$	9.4d	7/2			72Ek05			
$^{151}_{64}\text{Gd}$	120d	7/2			72Ek05			
$^{153}_{64}\text{Gd}$	242d	3/2			65Al16			
$^{155}_{64}\text{Gd}$			$-0.2584^b\ 5$ $\Omega=-1.6\ 6$	+1.59 16	69Un02	$^9D_3$ $^9D_2$ $^9D_4$ $^9D_5$ $^9D_6$		$a=4.9204\ 18$ $b=-406.670\ 6$ $c=-0.0015\ 5$ $a=36.5753^i\ 9$ $b=179.407^i\ 44$ $a=-6.8612^i\ 49$ $b=-352.834^i\ 38$ $a=-11.5125^i\ 39$ $b=41.977^i\ 40$ $a=-12.2424^i\ 12$ $b=587.893^i\ 12$ $a=47.9591^i\ 76$ $b=191.161^i\ 72$ $a=6.4456^i\ 22$ $b=-433.234^i\ 13$ $a=-8.9967^i\ 49$ $b=-375.884^i\ 38$ $a=-15.0955^i\ 38$ $b=44.744^i\ 39$ $a=-16.0573^i\ 57$ $b=626.275^i\ 60$
$^{157}_{64}\text{Gd}$			$-0.339^{\pm}\ 3$	+1.69 $\pm\ 17$	69Un02	$^9D_2$ $^9D_3$ $^9D_4$ $^9D_5$ $^9D_6$		#Using ratios from paramagnetic resonance
$^{159}_{64}\text{Gd}$	18h	3/2			61Ca07			
$^{151}_{65}\text{Tb}$	18h	1/2			70Ad09			
$^{152}_{65}\text{Tb}$	18h	2			70Ad09			
$^{153}_{65}\text{Tb}$	2.3d	5/2			70Ad09			
$^{154}_{65}\text{Tb}$	21h	0*	$< 10^{-4}$ , if $I=1$		70Ad09			
$^{154m}_{65}\text{Tb}$	8.5h	3			70Ad09			
$^{155}_{65}\text{Tb}$	5.6d	3/2			70Ad09			
$^{156}_{65}\text{Tb}$	5.4d	3			70Ad09			
$^{159}_{65}\text{Tb}$				+1.45*† 17	70Ch26	$^6H_{15/2}$ $^6H_{13/2}$		$a=673.753\ 2$ $b=1449.330\ 40$ $c=-0.001\ 2$ $a=682.911\ 3$ $b=1167.489\ 50$ $c=-0.001\ 2$
$^{159}_{65}\text{Tb}(70\text{Ch}26)$	continued							†For all $(4f^96s^2)$ -states

Table F: Nuclear Moments by Atomic and Molecular Beams — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^{159}\text{Tb}$ (70Ch26)		continued		+1.33*‡ 12 or +1.28*‡ 14	70Ch26	$^8\text{G}_{13/2}$		$a=532.204\ 2$ $b=928.861\ 30$ $c=0.001\ 2$
$^{160}\text{Tb}$	73d	3		+1.34*† 11	61Ca07		Interaction constants and $g_J$ -values for 14 other ( $4f^96s^2$ ) or ( $4f^85d\ 6s^2$ ) states given	‡For all ( $4f^85d6s^2$ )-states
$^{161}\text{Tb}$	6.9d	3/2			64Bu09		†Weighted average	
$^{149}\text{Dy}$	?	‡			70Ro21			‡Could not observe activity. If $I=7/2$ , then $T_{1/2} < 10\text{m}$ or $\approx T_{1/2}(^{151}\text{Dy})$
$^{151}\text{Dy}$	18m	7/2			70Ro21			
$^{152}\text{Dy}$	2.4h	0*			70Ro21	$^5\text{I}_8$	<20kHz, if $I=1$	
$^{153}\text{Dy}$	6.4h	7/2			70Ro21			
$^{153}\text{Dy}$	6.4h	7/2	$\pm 0.71^*\pm 9$ $\mu/Q$ positive	$\pm 0.14^*\pm 8$	72Ro36	$^5\text{I}_8$		$a=123.5\ 8$ $b=65.40$
$^{155}\text{Dy}$	10h	3/2			70Ro21			‡Based on $\mu^{161}$ and $Q^{*161}$ (72Ro36)
$^{155}\text{Dy}$	10h	3/2	$\pm 0.34^*\pm 3$ $\mu/Q$ negative	$\pm 0.91^*\pm 10$	72Ro36	$^5\text{I}_8$		$a=136.5\ 5$ $b=421.5$
$^{157}\text{Dy}$	8.1h	3/2			70Ro21			‡Based on $\mu^{161}$ and $Q^{*161}$ (72Ro36)
$^{157}\text{Dy}$	8.1h	3/2	$\pm 0.30^*\pm 4$ $\mu/Q$ negative	$\pm 1.22^*\pm 13$	72Ro36	$^5\text{I}_8$		$a=121.605\ 4$ $b=564.65\ 7$
$^{159}\text{Dy}$	144d	3/2			65Al16	$^5\text{I}_8$		‡Based on $\mu^{161}$ and $Q^{*161}$ (72Ro36)
$^{161}\text{Dy}$		5/2			62Sp03			
$^{161}\text{Dy}$		5/2	-0.47 9	+2.36 4	67Eb01	$^5\text{I}_8$		$a=-115.8\ 10$ $b=+1102.15$
$^{161}\text{Dy}$								$a=-116.231\ 2$ $b=1091.577\ 50$ $c=-0.002\ 5$ $a=-126.787\ 2$ $b=1009.742\ 60$ $c=0.000\ 5$
$^{161}\text{Dy}$			-0.46 5	+2.37 28	70Ch31	$^5\text{I}_8$		
$^{161}\text{Dy}$								
$^{161}\text{Dy}$						$^5\text{I}_7$		
$^{161}\text{Dy}$				$Q_4 \sim +58^p$	72Da38	$^5\text{I}_8$ ( $4f^{10}6s^2$ )		$a=-116.23218\ 20$ $b=1091.5740\ 75$ $c=-790.650\text{Hz}$ $d=-95.75\text{Hz}$
$^{161}\text{Dy}$								
$^{161}\text{Dy}$			-0.4792 <sup>kp</sup> 50		72Fe20			
$^{161}\text{Dy}$			-0.48 <sup>c</sup> 4	+2.35* <sup>c</sup> 26	72Ro36	$^5\text{I}_8, ^5\text{I}_7$		
$^{163}\text{Dy}$		5/2			(70Ch31)			
$^{163}\text{Dy}$		5/2	+0.66 13	+2.46 4	62Sp03			$a=+162.9\ 6$ $b=+1150\ 20$
$^{163}\text{Dy}$					67Eb01	$^5\text{I}_8$		$a=162.754\ 2$ $b=1152.869\ 40$ $c=0.001\ 4$ $a=177.535\ 2$ $b=1066.430\ 60$ $c=0.002\ 6$
$^{163}\text{Dy}$								

Table F: Nuclear Moments by Atomic and Molecular Beams - Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^{163}\text{Dy}$				$Q_4 \sim +67^p$	72Da38	$^5\text{I}_8(4f^{10}6s^2)$		$a=162.754272\ 20$ $b=1152.8635\ 12$ $c=-20\ 130\text{Hz}$ $d=-109\ 35\text{Hz}$
$^{163}\text{Dy}$			+0.6707 <sup>kp</sup> 35		72Fe20			
$^{163}\text{Dy}$			+0.67 <sup>sc</sup> ‡ 6	+2.48* <sup>c</sup> ‡ 27	72Ro36 (70Ch31)	$^5\text{I}_8$	‡Based on $\mu$ and $Q^{*161}$ (72Ro36)	
$^{165}\text{Dy}$	2.3h	7/2	±0.50	±3.2	61Ca07			$a=89.8\ 7$ $b=1521\ 30$
$^{165}\text{Dy}$	2.3h		$\mu/Q$ negative		68Ra03	$^5\text{I}_8$		
$^{165}\text{Dy}$			±0.52 <sup>sc</sup> ‡ 4	±3.27* <sup>c</sup> ‡ 37	72Ro36 (68Ra03)	$^5\text{I}_8$	‡Based on $\mu^{161}$ and $Q^{*161}$ (72Ro36)	
$^{166}\text{Dy}$	82h	0*	$\leq 10^{-4}$ , if $I=1$		61Ca07	$^5\text{I}_8$		
$^{153}\text{Ho}$	?	‡			69Ek01		‡Did not observe resonances at frequencies for $I=1/2$ to $11/2$ . $T_{1/2}$ possibly less than 9m.	
$^{154}\text{Ho}$	12m	1			69Ek01			
$^{155}\text{Ho}$	50m	5/2			69Ek01			
$^{156}\text{Ho}$	55m	1			69Ek01			
$^{157}\text{Ho}$	14m	7/2			69Ek01			
$^{158}\text{Ho}$	11m	5			69Ek01			
$^{158m}\text{Ho}$	29m	2			69Ek01			
$^{159}\text{Ho}$	33m	7/2			69Ek01			
$^{160}\text{Ho}$	26m	5			69Ek01			
$^{160m}\text{Ho}$	5.0h	2			69Ek01			
$^{161}\text{Ho}$	2.5h	7/2			64Bu09	$J=15/2$		
$^{161}\text{Ho}$	2.5h	7/2			69Ek01			
$^{162}\text{Ho}$	15m	1			69Ek01			
$^{162m}\text{Ho}$	68m	6			69Ek01			
$^{164}\text{Ho}$	29m	1			69Ek01			
$^{164m}\text{Ho}$	38m	6			69Ek01			
$^{165}\text{Ho}$					62Go20	$^4\text{I}_{15/2}$		$a=800.583\ 3$ $b=-1667.950\ 50$
$^{165}\text{Ho}$			+4.23	+2.99	62Wy04			
$^{165}\text{Ho}$			+4.01 <sup>c</sup> 8	+2.82 <sup>c</sup> 5	63Bi25			
$^{165}\text{Ho}$			+4.1 4	+2.4	64Go09	$^4\text{I}_{15/2}; 9, 8$ 8, 7 7, 6 6, 5 5, 4	7184.829 10 6540.836 10 5842.368 10 5096.265 10 4309.281 10	$a=800.58389\ 50$ $b=-1667.997\ 50$
$^{165}\text{Ho}$			+4.12 2		68Ha25			
$^{165}\text{Ho}$			+4.08 <sup>ci</sup> 8		68Su04			
$^{165}\text{Ho}$					(64Go09)			
$^{165}\text{Ho}$					72Da38	$^4\text{I}_{15/2}$		$a=800.583169\ 36$ $b=-1668.0789\ 33$ $c=-217\ 140\text{Hz}$ $d=-151\ 16\text{Hz}$
$^{165}\text{Ho}$					72Ha45	$^4\text{I}_{15/2}$		$g=6.370\times 10^{-4}\ 70$
$^{165}\text{Ho}$					72Me16	$^4\text{I}_{15/2}$		$a=800.5828\ 14$ $b=-1668.100\ 91$ $c=-2224\ 7520\text{Hz}$ $d=-398\ 790\text{Hz}$
$^{166}\text{Ho}$	27h	0*	$\leq 10^{-4}$ , if $I=1$		61Ca07	$^4\text{I}_{15/2}$		$a<5\text{kHz}$ , if $I=1$
$^{166}\text{Ho}$	27h	0*			61Ch06	$^4\text{I}_{15/2}$		

Table F: Nuclear Moments by Atomic and Molecular Beams — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^{157}\text{Er}$	20m	3/2			69Ek01	$^3\text{H}_6$		
$^{158}\text{Er}$	2.3h	0 <sup>a</sup>			69Ek01	$^3\text{H}_6$	<20kHz, if $I=1$	
$^{159}\text{Er}$	36m	3/2			69Ek01	$^3\text{H}_6$	<20kHz, if $I=1$	
$^{160}\text{Er}$	29h	0 <sup>a</sup>			69Ek01	$^3\text{H}_6$		
$^{161}\text{Er}$	3.2h	3/2			69Ek01	$^3\text{H}_6$		
$^{161}\text{Er}$	3.2h		-0.369 <sup>a</sup> 5	+1.20 <sup>a</sup> 9	72Ek03	$^3\text{H}_6$		$a=183.8 \ 14$ $b=1738 \ 10$
$^{163}\text{Er}$	1.2h	5/2			69St05	$^3\text{H}_6$		
$^{163}\text{Er}$	1.2h		+0.56 <sup>a</sup> 3	+2.2 <sup>a</sup> 2	72Ek03	$^3\text{H}_6$		$a=167 \ 7$ $b=3275 \ 130$
$^{165}\text{Er}$	10h	5/2			64Bu09	$J=6$		
$^{165}\text{Er}$	10h		$\pm 0.65^a \ 3$	$\pm 2.2 \ 1$	65Al10	$^3\text{H}_6$		$a=195 \ 6$ $b=3502 \ 115$
$^{167}\text{Er}$		7/2			62Sp02			
$^{167}\text{Er}$			-0.564 <sup>a</sup> 7	+2.82 <sup>c</sup>	63Bl25			$a=-120.4864 \ 5$ $b=-4552.959 \ 23$
$^{167}\text{Er}$			-0.5647 <sup>a</sup> 24	+2.827 12	65Sm04	$^3\text{H}_6$		$g=-0.8720 \times 10^{-4} \ 37$
$^{169}\text{Er}$	9.4d	1/2			61Ca07	$^3\text{H}_6$		
$^{169}\text{Er}$	9.4d		$\pm 0.513 \ 25$		63Do09	$^3\text{H}_6$		$g=5.55 \times 10^{-4} \ 27$
$^{171}\text{Er}$	7.5h	5/2			61Ca07	$^3\text{H}_6$		$a=725.46 \ 31$
$^{171}\text{Er}$	7.5h		$\pm 0.70^a \ 5$	$\pm 2.4 \ 2$	64Bu09	$^3\text{H}_6$		$a=197.0 \ 29$ $b=3646 \ 106$
$^{159}\text{Tm}$	9m	5/2			71Ek01			
$^{160}\text{Tm}$	9m	1			71Ek01			
$^{161}\text{Tm}$	37m	7/2			71Ek01			
$^{161m}\text{Tm}$	7m	‡			71Ek01			‡ Could not observe this activity; searched for $I=1/2$ through $9/2$
$^{162}\text{Tm}$	21m	1			71Ek01			
$^{162m}\text{Tm}$	77m	‡			71Ek01			‡ Could not observe this activity; searched for $I=0$ through 7
$^{163}\text{Tm}$	1.8h	1/2	$\pm 0.082 \ 2$		67Sc33	$^2\text{F}_{7/2}$		
$^{163m}\text{Tm}$	11m	‡			71Ek01			$a=133.4 \ 15$
$^{164}\text{Tm}$	2m	1			71Ek01			‡ Could not observe this activity; searched for $I=1/2$ through $9/2$
$^{164m}\text{Tm}$	5m	6			71Ek01			
$^{165}\text{Tm}$	29h	1/2			68Ek01			
$^{165}\text{Tm}$	29h	1/2	$\pm 0.138^a \ 2$		68Sc26	$^2\text{F}_{7/2}$		$a=224.4 \ 30$
$^{165m}\text{Tm}$	12m	‡			71Ek01			‡ Could not observe this activity; searched for $I=1/2$ through $9/2$
$^{166}\text{Tm}$	7.7h	2			61Wa04			
$^{166}\text{Tm}$	7.7h		$\pm 0.05^a \ 3$	$\pm 4.6 \ 7$	62Wa27	$^2\text{F}_{7/2}; ^{11/2}, ^9/2$ $^9/2, ^7/2$ $^7/2, ^5/2$ $^5/2, ^3/2$	4640 20 -330 30 -2800 100 -3390 130	$a=19 \ 6$ $b=7700 \ 300$
$^{166}\text{Tm}$	7.7h		$\mu/Q$ positive					
$^{167}\text{Tm}$	9.6d	1/2			61Wa04			
$^{167}\text{Tm}$	9.6d		-0.197 <sup>a</sup> 2		73An12	$^2\text{F}_{7/2}$		$a=318.5 \ 5$
$^{168}\text{Tm}$	85d	3			71Ek01			

Table F: Nuclear Moments by Atomic and Molecular Beams — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^{169}_{69}\text{Tm}$			$\pm 0.24^c$		62Li06			
$^{169}_{69}\text{Tm}$			-0.229 3		62Ri11	$^2\text{F}_{7/2}:4,3$	1496.555 10	$a=-374.1374 16$
$^{169}_{69}\text{Tm}$			-0.2310 <sup>b</sup> 15		67Gi04	$^2\text{F}_{7/2}:4,3$	1496.550667 <sup>j</sup> 12	$g=2.478 \times 10^{-4} 32$
$^{170}_{69}\text{Tm}$						4,3	1496.550642 12	$a=-374.137661 3$
$^{170}_{69}\text{Tm}$	127d	1	$\pm 0.26 2$	$\pm 0.61 5$	60Ca15	$^2\text{F}_{7/2}:^9/2, ^7/2$	74.20	$g=+2.498 \times 10^{-4} 15$
$^{170}_{69}\text{Tm}$			$\mu/Q$ positive			$^7/2, ^5/2$	1960.22	$a=200 3$
$^{170}_{69}\text{Tm}$	127d		$\pm 0.245^e 4$		63Bl25			$b=1010 15$
$^{170}_{69}\text{Tm}$	127d		$\pm 0.247^{ec} 4$		67Gi04			$(a=200 3)$
$^{171}_{69}\text{Tm}$	1.9y	1/2			61Ca07			
$^{171}_{69}\text{Tm}$	1.9y		$\pm 0.227^a 5$		64Bu09	$^2\text{F}_{7/2}$		$a=372.1 59$
$^{171}_{69}\text{Tm}$	1.9y		$\pm 0.230^{ec} 4$		67Gi04			$(a=372.1 59)$
$^{167}_{71}\text{Lu}$	54m	7/2			72Ek01			
$^{169}_{71}\text{Lu}$	1.5d	7/2			68Ek01			
$^{170}_{71}\text{Lu}$	2.0d	0 <sup>+</sup>			68Ek01	$^2\text{D}_{3/2}$		$a<0.020$ , if $I \neq 0$
$^{171}_{71}\text{Lu}$	8.3d	7/2			68Ek01			
$^{175}_{71}\text{Lu}$			+2.17 19	+5.68 6	62Ri04	$^2\text{D}_{3/2}:5,4$	2051.2305 40	$a=194.3316 4$
						4,3	345.4974 24	$b=1511.4015 30$
						3,2	-496.5777 8	$g=3.50 \times 10^{-4} 10$
						$^2\text{D}_{5/2}:6,5$	1837.579 10	$a=146.7790 8$
						5,4	800.3467 43	$b=1860.6480 80$
						4,3	161.8248 56	$g=3.13 \times 10^{-4} 24$
						3,2	-157.7283 51	
						2,1	-238.0556 40	
$^{175}_{71}\text{Lu}$					71Fi03	$^2\text{D}_{3/2}:5,4$	2051.220129 90	$a=194.33292 30$
					73Fi08	4,3	345.49662 30	$b=1511.39627 32$
						3,2	496.57800 10	$c=-70 19\text{Hz}$
						$^2\text{D}_{5/2}:6,5$	1837.57010 40	$a=146.77647 14$
						5,4	800.34261 33	$b=1860.65613 84$
						4,3	161.81548 50	$c=913 162\text{Hz}$
						2,1	238.05836 10	$d=-16 24\text{Hz}$
$^{176}_{71}\text{Lu}$	20Gy	7	$\pm 3.184^{\pm} 15$	$\pm 8.0 7$	62Sp03	$^2\text{D}_{3/2}:^{17}/2, ^{15}/2$	2486 10	$a=138.80 46$
						$^{15}/2, ^{13}/2$	775 5	$b=2151 10$
						$^{13}/2, ^{11}/2$	-404 9	$\ddagger$ Using $\mu_{unc}^{175}=2.211 10$ , 62Re02
$^{176m}_{71}\text{Lu}$	3.7h	1	+0.318* 3	-2.39 4	65Wh03	$^2\text{D}_{3/2}$		$a=+97.19644 30$
						$^2\text{D}_{5/2}$		$b=-635.19314 70$
$^{177}_{71}\text{Lu}$	6.8d	7/2	+2.235* 10	+5.51 6	62Pe07	$^2\text{D}_{3/2}:5,4$	2021.850 130	$a=+73.17285 30$
						4,3	360.300 85	$b=-781.97469 70$
						3,2	-463.130 105	
						$^2\text{D}_{5/2}:6,5$	1811.784 95	$a=147.17 1$
						5,4	800.348 50	$b=1805.93 14$
						4,3	175.896 50	
						3,2	-138.968 55	
						2,1	-221.640 45	
$^{177}_{72}\text{Hf}$			+0.7902 <sup>b</sup> 7	+4.5* 5	73Bu25	$^3\text{F}_2: ^{11}/2, ^9/2$	991.79202 24	$a=113.43314 7$
						$^9/2, ^7/2$	477.00847 21	$b=624.3293 13$
						$^7/2, ^5/2$	162.88685 15	$c=270 180\text{Hz}$
						$^5/2, ^3/2$	4.86356 32	$d=45 40\text{Hz}$
								$g = -1.2194 \times 10^{-4} 9$

Table F: Nuclear Moments by Atomic and Molecular Beams — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^{179}\text{Hf}$			-0.6382 <sup>b</sup> 13	+5.1* 5	73Bu25	$^3\text{F}_2: ^{13}/_2, ^{11}/_2$ $^{11}/_2, ^9/_2$ $^9/_2, ^7/_2$ $^7/_2, ^5/_2$	82.13214 60 392.84775 37 541.91044 7 558.67174 24	$a=-71.42891\ 9$ $b=705.5181\ 24$ $c=-430\ 200\text{Hz}$ $d=70\ 60\text{Hz}$ $g=0.7660\times 10^{-4}\ 15$
$^{181}\text{Ta}$					71Bu10	$^4\text{F}_{3/2}: 5, 4$ 4, 3 $^4\text{F}_{5/2}: 6, 5$ 5, 4 4, 3 $^4\text{F}_{7/2}: 4, 3$	1822.389 6 2325.537 2 1451.476 7 1537.530 8 1444.685 2 1218.372 2	$a=509.0801\ 8$ $b=-1012.251\ 8$ $a=313.4681\ 8$ $b=834.820\ 12$
$^{183}\text{Ta}$	5.0d	7/2			63Do13			
$^{185}\text{W}$	74d	3/2			63Do13			
$^{187}\text{W}$	24h	3/2			63Do13			
$^{186}\text{Re}$	90h	1			63Do13			
$^{186}\text{Re}$	90h		+1.730 <sup>b</sup> 3		65Ar01	$^6\text{S}_{5/2}$		$a=-78.3060\ 10$ $b=+8.3595\ 16$ $g=+9.34\times 10^{-4}\ 2$
$^{186}\text{Re}$	90h		positive		65Sc13	$^6\text{S}_{5/2}: ^7/_2, ^5/_2$ $^5/_2, ^3/_2$	265.292 14 208.305 14	$a=78.3058\ 24$ $b=8.3601\ 50, b/a<0$
$^{186}\text{Re}$	90h			~0.4°	66Ku07 (65Ar01)			
$^{188}\text{Re}$	17h	1			63Do13			
$^{188}\text{Re}$	17h		+1.780 <sup>b</sup> 5		65Ar01	$^6\text{S}_{5/2}$		$a=80.4326\ 8$ $b=7.7463\ 11, b/a<0$ $g=+9.61\times 10^{-4}\ 3$
$^{188}\text{Re}$	17h		positive		65Sc13	$^6\text{S}_{5/2}: ^7/_2, ^5/_2$ $^5/_2, ^3/_2$	273.379 13 212.698 17	$a=80.4320\ 32$ $b=7.7455\ 60, b/a<0$
$^{188}\text{Re}$	17h			~0.4°	66Ku07 (65Ar01)			
$^{191}\text{Ir}$				±0.78 20	73Bu15	$^4\text{F}_{9/2}: 6, 5$ 5, 4 4, 3	659.26496 12 189.44002 9 84.05040 80	$a=57.52148\ 4$ $b=471.20425\ 57$ $c=-20\ 30\text{Hz}$
$^{192}\text{Ir}$	74d	4			63Do13			
$^{193}\text{Ir}$				±0.70 18	73Bu15	$^4\text{F}_{9/2}: 6, 5$ 5, 4 4, 3	660.09043 12 224.47848 13 33.53453 89	$a=62.65556\ 5$ $b=426.23546\ 64$ $c=20\ 30\text{Hz}$
$^{194}\text{Ir}$	19h	1			63Do13			
$^{195}\text{Pt}$					67Ch26	$^3\text{D}_3$ $^3\text{D}_2$		$a=5717\ 21$ $a=2608\ 3$
$^{195}\text{Pt}$					71Gr61	$^3\text{F}_4: ^9/_2, ^7/_2$	3820.564 7	$a=849.014\ 2$
$^{197}\text{Pt}$	20h	1/2	±0.50* 2		68Ch18			
$^{199}\text{Au}$	40m	1	±0.063		64Li06	$^2\text{S}_{1/2}: ^3/_2, ^1/_2$	3004 7	
$^{199}\text{Au}$	40m	1	±0.065* 9		66Ch05	$^2\text{S}_{1/2}: ^3/_2, ^1/_2$	3105 425	
$^{191}\text{Au}$	3.0h	3/2			60Ew06			
$^{191}\text{Au}$	3.0h		±0.137* 7		64Ew02	$^2\text{S}_{1/2}: 2, 1$	5770 6	
$^{192}\text{Au}$	4.1h	1	±0.0079* 1		60Ew06	$^2\text{S}_{1/2}: ^3/_2, ^1/_2$	372.1 1	
					(59E88)			
$^{193}\text{Au}$	18h	3/2			60Ew06			
$^{193}\text{Au}$	18h		±0.139* 7		64Ew02	$^2\text{S}_{1/2}: 2, 1$	5882 10	

Table F: Nuclear Moments by Atomic and Molecular Beams — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^{194}\text{Au}$	39h		$\pm 0.076^* 3$		57H69	$^2\text{S}_{1/2}; ^3/2, ^1/2$	3600 120	
$^{194}\text{Au}$	39h	1	$\pm 0.074^* 4$		60Ew06	$^2\text{S}_{1/2}; ^3/2, ^1/2$	3489.865 32	
$^{194}\text{Au}$	39h		$\pm 0.074^* 4$		65Ch08	$^2\text{S}_{1/2}; ^3/2, ^1/2$	3489.865 32	
$^{195}\text{Au}$	192d	3/2			60Ew06	$^2\text{S}_{1/2}; ^3/2, ^1/2$	3489.865 32	
$^{195}\text{Au}$	192d		$\pm 0.147^* 7$		65Ch08	$^2\text{S}_{1/2}; 2, 1$	6220 38	
$^{196}\text{Au}$	6.2d	2			60Ew06	$^2\text{S}_{1/2}; ^5/2, ^3/2$	21347.2522 15	
$^{196}\text{Au}$	6.2d		$+0.5879^k 14$		70Sc07	$^2\text{S}_{1/2}; ^5/2, ^3/2$	21347.2522 15	
$^{196m}\text{Au}$	9.7h	12			62Ch13	$^2\text{S}_{1/2}$		
$^{197}\text{Au}$			$\pm 0.13 1$		53W33	$^2\text{S}_{1/2}; 2, 1$	6107.1 10	
$^{197}\text{Au}$				+0.585	66Ch03	$^2\text{D}_{5/2}; 4, 3$	518.880 17	$a=80.236 3$
						3, 2	713.101 8	$b=1049.781 11, b/a < 0$
						2, 1	1000.304 10	$c=0.0004 4, c/a > 0$
						$^2\text{D}_{3/2}$		
				+0.598 <sup>c</sup>				
				+0.592 <sup>‡</sup> 12				
$^{197}\text{Au}$			$\Omega=+0.0098 7$	+0.604	67Bl16	$^2\text{D}_{3/2}; 3, 2$	311.5473 2	$a=199.8425 2$
			to +0.014 1			2, 1	1310.7555 12	$b=-911.0766 5$
						1, 0	1110.9315 5	$c=0.000212 14$
			$\Omega=+0.15$			$^4\text{F}_{9/2}; 6, 5$	2233.7160 14	$a=432.276 1$
						5, 4	2273.8874 6	$b=-540.026 1$
						4, 3	2089.1430 4	$c=0.00326 10$
$^{197}\text{Au}$			$\Omega=+0.06 6$	(+0.585)	(66Ch03)	$^2\text{D}_{5/2}$		
				+0.594 <sup>‡</sup>				
$^{198}\text{Au}$	2.7d	2	$+0.144865^b 70$		67Da04	$^2\text{S}_{1/2}; 2, 1$	6099.320184 13	
$^{198}\text{Au}$			$+0.552^* 4$ if $\mu > 0$		56C08	$^2\text{S}_{1/2}; ^5/2, ^3/2$	21800 150 if $\mu > 0$	
			$-0.570^* 4$ if $\mu < 0$				22500 150 if $\mu < 0$	
$^{198}\text{Au}$	2.7d		$+0.5898^d 5$		67Va16	$^2\text{S}_{1/2}; ^5/2, ^3/2$	21450.7167 4	$g=1.5908 \times 10^{-4} 6$
$^{199}\text{Au}$	3.2d	3/2	$\pm 0.264^* 5$		56C08	$^2\text{S}_{1/2}; 2, 1$	11110.130 if $\mu > 0$	
							11180.130 if $\mu < 0$	
$^{199}\text{Au}$	3.2d		$+0.2699^d 7$		67Va16	$^2\text{S}_{1/2}; 2, 1$	10962.7227 3	$g=0.9706 \times 10^{-4} 12$
$^{199}\text{Hg}$								
$^{201}\text{Hg}$			$\Omega=-0.13 1$	+0.50 4	60Mc11	$^3\text{P}_2; ^5/2, ^3/2$	22666.559 5	$a=9066.449 3$
					60Mc11	$^3\text{P}_2; ^7/2, ^5/2$	11382.6288 8	$a=-3352.0292 8$
						$^5/2, ^3/2$	8629.5218 5	$b=399.150 2$
						$^3/2, ^1/2$	5377.4918 20	$c=-0.00184 9$
$^{201}\text{Hg}$								
$^{193}\text{Tl}$	23m	1/2			73Ek03			
$^{194}\text{Tl}$	33m	2	$\pm 0.135 3$		73Ek03	$^2\text{P}_{1/2}$		$a=443 9$
$^{195}\text{Tl}$	1.2h	1/2			62Ax02			
$^{195}\text{Tl}$	1.2h		$+1.66 13$		73Ek03			$g=+1.79 \times 10^{-3} 14$
$^{196}\text{Tl}$	1.8h	2	$\pm 0.0699 2$		73Ek03	$^2\text{P}_{1/2}$		$a=228.8 6$
$^{197}\text{Tl}$	2.8h	1/2			57B132			
$^{197}\text{Tl}$	2.7h		$+1.66 13$		73Ek03			$g=+1.79 \times 10^{-3} 14$
$^{198}\text{Tl}$	5.3h	2	$\pm 2 \times 10^{-3}$		58L45			
$^{198}\text{Tl}$	5.3h		$\pm 0.0012063 9$		73Ek03	$^2\text{P}_{1/2}$		$a=3.9499 6$
$^{198m}\text{Tl}$	1.8h	7			57B132			
					74EkZX	$^2\text{P}_{1/2}$		$a=599 69$
$^{199}\text{Tl}$	7.4h	1/2			57B132			
$^{199}\text{Tl}$	7.4h		$+1.65 10$		73Ek03			$g=+1.78 \times 10^{-3} 11$
$^{200}\text{Tl}$	26.1h	2			58M21			
$^{200}\text{Tl}$	26.1h		$\pm 0.035675 28$		73Ek03	$^2\text{P}_{1/2}$		$a=116.814 8$

Table F: Nuclear Moments by Atomic and Molecular Beams — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^{201}_{81}\text{Tl}$	73.5h	1/2			58L45			
$^{201}_{81}\text{Tl}$	73.5h	1/2		+1.71 11	58M21			$g=+1.84 \times 10^{-3} 12$
$^{201}_{81}\text{Tl}$	73.5h				73Ek03			
$^{202}_{81}\text{Tl}$	12.2d	2			58M35			
$^{202}_{81}\text{Tl}$	12.2d			$\pm 0.565$	73Ek03	$^2\text{P}_{1/2}$		$a=185.1 7$
$^{203}_{81}\text{Tl}$					56L53	$^2\text{P}_{1/2}; 1, 0$	21105.447 5	
$^{203}_{81}\text{Tl}$				+1.6109 <sup>bp</sup> 14	68Fo10	$^2\text{P}_{3/2}; 2, 1$	524.05994 10	$g=17.375 \times 10^{-4} 14$
$^{203}_{81}\text{Tl}$					68Pa07	$^2\text{P}_{1/2}; 1, 0$	21105.4497638 5	
$^{203}_{81}\text{Tl}$					68Pe18	$6^2\text{P}_{3/2}; 2, 1$	524.059953 3	
$^{204}_{81}\text{Tl}$	3.9y	2	$\pm 0.062^* 6$		56B124			$a=200 20$
$^{204}_{81}\text{Tl}$	3.9y	2	$\pm 0.0894^* 20$		57B132	$^2\text{P}_{1/2}; ^5/2, ^3/2$	732 5	
$^{204}_{81}\text{Tl}$	3.9y		$\pm 0.0893^* 1$		58W44	$^2\text{P}_{1/2}; ^5/2, ^3/2$	730.837 5	
$^{205}_{81}\text{Tl}$				$\pm 1.6265 9$	56L53	$^2\text{P}_{1/2}; 1, 0$	21310.835 5	
$^{205}_{81}\text{Tl}$					64Bo37		TlF	
$^{205}_{81}\text{Tl}$				+1.6271 <sup>bp</sup> 15	67La23	$^2\text{P}_{1/2}; 1, 0$	21310.8339466 2	
$^{205}_{81}\text{Tl}$					68Fo10	$^2\text{P}_{3/2}; 2, 1$	530.07655 10	$g=17.549 \times 10^{-4} 14$
$^{205}_{81}\text{Tl}$					68Pe18	$6^2\text{P}_{3/2}; 2, 1$	530.076546 3	
$^{206}_{81}\text{Tl}$	4.2m	0*	$<10^{-5}$ , if $I=1$		69Cu09	$J=1/2$		$a < 163 \text{ kHz}$
$^{207}_{82}\text{Pb}$					70Lu09	$^1\text{D}_2; ^5/2, ^3/2$	1524.545 20	$a=609.820 8$
$^{199}_{83}\text{Bi}$	25m	9/2			59A198			
$^{200}_{83}\text{Bi}$	35m	7			59A198			
$^{201}_{83}\text{Bi}$	1.8h	9/2			59A198			
$^{201m}_{83}\text{Bi}$	62m		$I>21/2$ or $\mu<0.1^{\ddagger}$		59A198			$\ddagger$ If this activity were produced with about the same probability as the ground state, a resonance should have been observed unless $I$ were very large or $\mu$ very small
$^{202}_{83}\text{Bi}$	1.6h	5			59A198			
$^{203}_{83}\text{Bi}$	12h	9/2	+4.59* 5	-0.64 5	59L50	$J=3/2; 6, 5$ 5, 4	3386 30 2396 15	$a=-502.4 30$ $b=-558 25$
$^{204}_{83}\text{Bi}$	12h	6	+4.25* 5	-0.41 5	59L50	$J=3/2; ^{15}/2, ^{13}/2$ $^{13}/2, ^{11}/2$	2841 25 2216 15	$a=-349.0 20$ $b=-358 20$
$^{205}_{83}\text{Bi}$	15d	9/2	$\approx +5.5^{\ddagger}$		59L50	$J=3/2; 6, 5$	$\approx 4000$	$a \approx -600$
								$\ddagger$ Value very uncertain due to large configuration interaction corrections which are not included
$^{206}_{83}\text{Bi}$	6.3d	6			57M24			
$^{206}_{83}\text{Bi}$	6.3d	6	+4.56* 5	-0.19 5	59L50	$J=3/2; ^{15}/2, ^{13}/2$ $^{13}/2, ^{11}/2$	2914.25 2411.20	$a=-374.7 30$ $b=-166 30$
$^{209}_{83}\text{Bi}$	>2Ay			-0.34	60Ti01	$J=3/2; 6, 5$ 5, 4	2884.7 2 2171.5 1	$a=-446.97 4$ $b=-304.25 83$
$^{209}_{83}\text{Bi}$	>2Ay			-0.29 <sup>c</sup>	62Ko22			
$^{209}_{83}\text{Bi}$	>2Ay			-0.35	68Lu08	$^2\text{P}_{3/2}; 6, 5$ 5, 4 4, 3	3598.647 6 2251.038 10 1311.930 10	
$^{209}_{83}\text{Bi}$	>2Ay		$\Omega=+0.43$		70Hu05	$^4\text{S}_{3/2}; 6, 5$ 5, 4 4, 3	2884.666 2 2171.419 2 1584.502 2	$a=-446.937 1$ $b=-305.067 2$ $c=0.0183 1$
$^{209}_{83}\text{Bi}$	>2Ay		+4.25 14 $\Omega=+0.55^{\ddagger} 3$	-0.383 40	70La07	$^2\text{P}_{3/2}$		$a=491.028 1$ $b=978.639 9$ $c=0.0193 5$
$^{209}_{83}\text{Bi}$	>2Ay		$\Omega=0.62^* 8$	-0.46 <sup>c</sup>	72Ro37	$^4\text{S}_{3/2}, ^2\text{D}_{3/2}, ^2\text{P}_{3/2}$ $^4\text{S}_{3/2}, ^2\text{P}_{3/2}$	#Used $\mu=4.08$	

Table F: Nuclear Moments by Atomic and Molecular Beams - Continued

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Atomic State: ( $F, F'$ )	$\Delta\nu(F, F')$ or Molecule Used	Interaction Constants or Moment Ratios
$^{210}_{83}\text{Bi}$	5d	1			54S96			
$^{210}_{83}\text{Bi}$	5d		$\pm 0.0442^a I$ $\mu/Q$ negative	$\pm 0.13 I$	62Al02	$J=^3/2; ^5/2, ^3/2$ $^3/2, ^1/2$	194.93 9 220.19 8	$a=21.78 3$ $b=112.38 3$
$^{210}_{83}\text{Bi}$	5d		negative	positive‡	64Po04			‡From fitting experimental values of $\mu$ and $Q$ and $\beta$ -decay data to deduce reasonable $\Psi$ 's
$^{201}_{84}\text{Po}$	18m	3/2			61Ax02			
$^{202}_{84}\text{Po}$	51m	0 <sup>+</sup>			61Ax02			$a<0.02$ , if $I=1$
$^{203}_{84}\text{Po}$	42m	5/2			61Ax02			
$^{204}_{85}\text{Po}$	3.5h	0 <sup>+</sup>			61Ax02			$a<0.02$ , if $I=1$
$^{205}_{84}\text{Po}$	1.8h	5/2			61Ax02			
$^{205}_{84}\text{Po}$	1.8h		$\approx \pm 0.26^a \ddagger$	+0.17	68Jo19			$a=134.14 2$ $b=232.3 2$
								‡Value very uncertain due to large configuration interaction corrections which are not included
$^{206}_{84}\text{Po}$	8.8d	0 <sup>+</sup>			61Ax02			$a<0.02$ , if $I=1$
$^{207}_{84}\text{Po}$	6.0h	5/2			61Ax02			
$^{207}_{84}\text{Po}$	6.0h		$\approx +0.27^a \ddagger$ $\Omega=+0.11 I$	+0.28	61Ol01	$J=2; ^9/2, ^7/2$ $^7/2, ^5/2$ $^5/2, ^3/2$	884.785 13 421.950 8 158.567 12	$a=139.551 2$ $b=380.548 16$ $c=-0.0120 10$
								‡Value very uncertain due to large configuration interaction corrections which are not included
$^{210}_{84}\text{Po}$	138d	0 <sup>+</sup>			61Al20			
$^{211}_{85}\text{At}$	7.2h	9/2			58G16			
$^{233}_{91}\text{Pa}$	27d	3/2			58H115			
$^{233}_{91}\text{Pa}$	27d	3/2	+3.4 8	-3.0	61Ma42			$g=12.5 \times 10^{-4} 30$ $a=+595 30$ $b=-2400 300$
$^{238}_{93}\text{Np}$	2.1d	2			58A92			
$^{239}_{93}\text{Np}$	2.3d	5/2			58H111			
$^{239}_{94}\text{Pu}$	24ky	1/2	$\pm 0.02$		58H70	$^7\text{F}_1; ^3/2, ^1/2$	7.683 60	$a=5.14$
$^{239}_{94}\text{Pu}$	24ky		+0.200 <sup>b</sup> 4		65Fa02			
$^{241}_{95}\text{Am}$	460y	5/2			60Ma30	$^8\text{S}_{7/2}$		$a=17.144 8$ $b=123.82 10$ $b/a < 0$
$^{241}_{95}\text{Am}$	460y		+1.59 <sup>b</sup> 3		66Ar04	$^8\text{S}_{7/2}$		$a=17.1437 28$ $b=123.848 32$ , $b/a < 0$ $g=3.42 \times 10^{-4} 6$
$^{242}_{95}\text{Am}$	16h	1	$\pm 0.33$ $\mu/Q$ negative	$\pm 2.76$	61Ma27			$a=10.124 10$ $b=69.639 40$
$^{242}_{95}\text{Am}$	16h		+0.3826 <sup>b</sup> 15		66Ar04	$^8\text{S}_{7/2}$		$a=10.1282 14$ $b=69.6339 13$ $g=2.059 \times 10^{-4} 8$
$^{242}_{96}\text{Cm}$	160d	0 <sup>+</sup>	$< 2 \times 10^{-4}$ , if $I=1$		59H115			
$^{253}_{99}\text{Es}$	20.5d		$\pm 4.06^k 20$	$\pm 6.1$	72Go42			$a=816.57 60$ $b=-4335 16$

**Table F: Nuclear Moments by Atomic and Molecular Beams – Continued**

- \* Polarization or Sternheimer correction included
- ♦ No hyperfine structure observed
- ▲ Calculated from the  $\Delta\nu$ - or  $a$ -ratio for two isotopes
- Non-resonance or zero-moment experiment
- ◆ Recalculation of earlier data
- ◆ Determined from  $\Delta m = \pm 1$  doublet separation
- ◆ Electric resonance experiment
- ◆ Inferred from intensity or polarization distribution across the beam
- ◆ Calculated from the  $b$ -ratio for two isotopes
- ◆ Direct measurement by triple resonance
- ◆ No diamagnetic correction added. Unsure if authors already corrected for it.
- ◆ Not corrected for mixing of other states or higher order perturbation effects
- ◆ Direct measurement
- ◆ MASER experiment
- ◆ Metastable or excited state
- ◆ Preliminary value from meeting abstract, thesis, private communication, etc.

**Table G: Nuclear Moments by Optical Spectroscopy**

### Introduction

A nuclear angular momentum, designated by  $I$ , and an associated magnetic moment,  $\mu$ , were first postulated by Pauli [24Pa01] and by Goudsmit and Back [27Go01] to explain an observed hyperfine structure (hfs) in spectral lines of the order of magnitude of  $1\text{cm}^{-1}$  or roughly  $1/2000$  of the fine structure which is due to different orientations of the electron's spin with respect to its orbital angular momentum.

This hyperfine structure is attributed to the splitting of the energy levels of the atom as a result of the interaction between the nuclear magnetic moment and the magnetic field due to the electrons. Deviations from the expected magnitude of this splitting can be ascribed to the interaction of the nuclear electric quadrupole moment with the electric field.

The individual electronic states are split by the magnetic interaction into  $2I + 1$  or  $2J + 1$  substates depending upon whether  $I$  is less than or greater than  $J$ , the electronic spin. An observed spectral

line, arising from a transition between two such electronic states, will have a multiplicity greater than  $2I + 1$  or  $2J + 1$  unless  $J$  is zero for one of the states. Two typical transitions are illustrated in figure 1. If  $J$  is known for each of the states involved in the transition,  $I$  can be determined by the multiplicity and the relative spacings of the components. The statistical weights of the hyperfine substates are also functions of  $I$  so that the relative intensities of the hfs components may also indicate the nuclear spin.

A few nuclei have also been studied by molecular band spectroscopy. This technique has been used to make unequivocal assignments of zero spin by the observation of the absence of alternating intensities in the band spectra of diatomic homonuclear molecules. The method of atomic spectroscopy cannot establish a zero spin since only an upper limit can be placed on the hfs splitting by a study of the spectral lines.

Values of the nuclear magnetic dipole and electric quadrupole moments are calculated from the hyperfine interaction constants which are in turn computed from the wavelengths of the observed lines. Since the values of  $\mu$  determined in this way

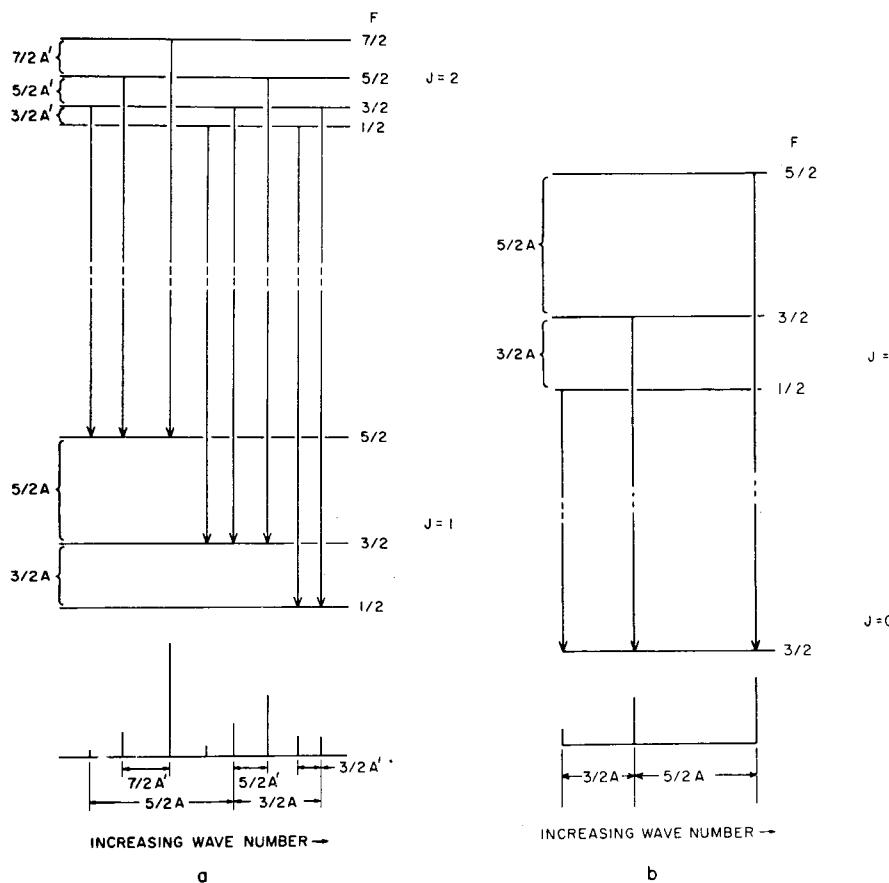


FIGURE 1. Schematic level diagram showing transitions between an upper and lower state in an atom where the nucleus has  $I=3/2$  and  $Q=0$  (a) for  $J_{\text{upper}}=2$  and  $J_{\text{lower}}=1$ , (b) for  $J_{\text{upper}}=1$ , and  $J_{\text{lower}}=0$ . The lower part of each diagram graphically depicts the relative wave numbers and intensities of the corresponding multiplets. The magnetic dipole interaction constants for the  $J=1$  and  $J=2$  states are denoted by  $A$  and  $A'$ , respectively.

are accurate only to a few percent, this table does not list all values measured by the optical method but only those not measured by more accurate techniques and those for which the sign of the moment was determined.

The calculation of the quadrupole moment  $Q$  from the interaction constant depends upon the determination of the electric field gradient at the nucleus. In some of the earlier calculations the wavefunctions used were very crude. No attempt has been made by the compilers to reevaluate the  $Q$ 's with newer wavefunctions. In addition, the nuclear quadrupole moment causes a polarization of the atomic core electrons (Sternheimer effect). The correction for this effect can be of the order of tens of percent.

There have been a few errors or ambiguities in assignment of spin by optical spectroscopy. These can be caused by such factors as

- (1) Errors in assignment of  $J$  to the states involved.
- (2) Isotopic impurities which may produce lines masking those under study.
- (3) Distortion of intensity ratios resulting from self-absorption, diffuse radiation background, or in the case of photographic recording, a nonlinearity of density response of the photographic material.

The precision with which hyperfine interactions can be determined by optical spectroscopy is limited by

- (1) Lifetimes of the excited energy levels, which are of the order of  $10^{-8}$  seconds and produce a line broadening of about  $3 \times 10^{-3} \text{ cm}^{-1}$ .
- (2) Doppler effect due to atomic motion. This can be reduced by cooling the source or using an atomic beam in which the motion of the atoms is perpendicular to the optical path.
- (3) The finite resolving power of the optical equipment. This involves both the inherent limitations of the system and the imperfections of preparation of optical surfaces.

A general review of the optical method can be found in F.M. Kelly, *Determination of Nuclear Spins and Magnetic Moments by Atomic Spectroscopy* [58Ke25]. Details of the techniques and apparatus are discussed in S. Tolansky, *High Resolution Spectroscopy* [47To19].

A few measurements of nuclear moments from the analysis of meson-atomic X-rays have also been included in this table. These values have been marked by a "<sup>1</sup>".

The last systematic literature search for information included in the table was in early 1971.

### Explanation of Table G

Nucleus	Chemical symbol with $Z$ - and $A$ -number States, other than ground states, are designated by "m" following the $A$ -number.
$T_{1/2}$	Half-life of radioactive nucleus
$I$	Nuclear spin, in units of $h/2\pi$
$\mu$ or $\mu^1/\mu^2$	Nuclear magnetic dipole moment, in nuclear magnetons, given with diamagnetic correction, or magnetic moment ratio. See Policies, Diamagnetic corrections, for factors used A 5% uncertainty in the diamagnetic correction is assumed.
$Q$ or $Q^1/Q^2$	Nuclear electric quadrupole moment, in barns, as given by the experimenter, or quadrupole moment ratio. Values marked by an asterisk, *, indicate that the experimenter has made some polarization or Sternheimer corrections in computing the moment.
Refer.	Reference key

Table G: Nuclear Moments by Optical Spectroscopy

Nucleus	$T_{1/2}$	$I$	$\mu$ or $\mu^1/\mu^2$	$Q$ or $Q^1/Q^2$	Refer.
$^1H$		1/2 <sup>b</sup>			29M01
$^1H$		1/2 <sup>b</sup>			30C01
$^1H$		1/2 <sup>b</sup>			30H02
$^2H$		1 <sup>b</sup>			33L02
$^2H$		1 <sup>b</sup>			34M03
$^3H$	12y	1/2 <sup>b</sup>			49D31
$^3He$		1/2 <sup>b</sup>			49D24
$^3He$			negative		50F51
$^4He$		0 <sup>b</sup>			29M01
$^7Li$		3/2 <sup>b</sup>			30H01
$^7Li$		3/2			32G03
$^{12}C$		0 <sup>b</sup>			29M01
$^{13}C$		1/2 <sup>bE</sup>			48J21
$^{14}C$	5.6ky	0 <sup>bE</sup>			48J21
$^{14}N$		1 <sup>b</sup>			28O01
$^{15}N$		1/2 <sup>bE</sup>			39K11
$^{15}N$		1/2 <sup>b</sup>			40W10
$^{16}O$		0 <sup>b</sup>			29M01
$^{19}F$		1/2 <sup>b</sup>			29G01
$^{19}F$		1/2			33C04
$^{20}Ne$		0 <sup>d</sup>			27H01
$^{21}Ne$		$\geq 3/2^E$	negative <sup>E</sup>		49K21
$^{21}Ne$				$\pm 0.0926^q 16$	71Du05
$^{22}Ne$		0 <sup>d</sup>			27H01
$^{23}Na$		3/2			33G03
$^{23}Na$		3/2 <sup>b</sup>			33J04
$^{23}Na$		3/2	$\pm 1.99^a$		34E02
$^{23}Na$			+2.14		34S05
$^{23}Na$			$\pm 2.218 13$		67Dr09
$^{24}Mg$		0 <sup>d</sup>			31M02
$^{25}Mg$		5/2	-0.96 7		49C18
$^{26}Mg$		0 <sup>d</sup>			31M02
$^{27}Al$		5/2	+3.7		38H06
$^{31}P$		1/2 <sup>b</sup>			33A01
$^{31}P$		1/2	+1.15 5		49C31
$^{32}S$		0 <sup>b</sup>			31N01
$^{32}S$		0 <sup>b</sup>			36O01
$^{36}Ar$		0 <sup>d</sup>			37K03
$^{36}Ar$		0 <sup>dE</sup>			53M73
$^{37}Ar$	34d	3/2	+0.95 20		65Ro13
$^{38}Ar$		0 <sup>dE</sup>			53M73
$^{39}Ar$	265y	7/2	-1.3 3		67Tr12
$^{40}Ar$		0 <sup>d</sup>			37K03
$^{40}Ar$		0 <sup>dE</sup>			53M73
$^{39}K$		3/2	positive		37J02

Table G: Nuclear Moments by Optical Spectroscopy - Continued

Nucleus	$T_{1/2}$	$I$	$\mu$ or $\mu^1/\mu^2$	$Q$ or $Q^1/Q^2$	Refer.
$^{40}_{20}\text{Ca}$		0 $\ddagger$			31F01
$^{43}_{20}\text{Ca}$		7/2	-1.2		54K14
$^{45}_{21}\text{Sc}$		7/2			34K01
$^{45}_{21}\text{Sc}$		7/2			34S01
$^{45}_{21}\text{Sc}$			+4.8		37K02
$^{51}_{23}\text{V}$		7/2			36K04
$^{51}_{23}\text{V}$				+0.28 15	56M36
$^{51}_{23}\text{V}$				+0.26 <sup>c</sup>	62Ko22
$^{55}_{25}\text{Mn}$		5/2			30W01
$^{55}_{25}\text{Mn}$			+3.0		39F03
$^{55}_{25}\text{Mn}$				+0.4* 2	55M56
$^{55}_{25}\text{Mn}$				+0.3 1	58R54
$^{55}_{25}\text{Mn}$				+0.35 5	62Wa30
$^{59}_{27}\text{Co}$		7/2			35K05
$^{59}_{27}\text{Co}$		7/2	+2.7		35M07
$^{59}_{27}\text{Co}$				+0.5 2	53M65
$^{59}_{27}\text{Co}$				$\pm 0.49$ 3	69Mu11
				$\pm 0.42*$ 3	
$^{61}_{28}\text{Ni}$			$\pm \leq 0.25^E$		50K55
$^{63}_{29}\text{Cu}$		3/2			32R02
$^{63}_{29}\text{Cu}$		3/2	+2.5	-0.1 1	36S07
$^{63}_{29}\text{Cu}$				-0.13 6	53K39
$^{63}_{29}\text{Cu}$				-0.28 7	56K64
$^{63}_{29}\text{Cu}$				-0.20 <sup>E</sup> 4	61Fi01
$^{63}_{29}\text{Cu}$				-0.181 <sup>c</sup>	62Ko22
					(61Fi01)
$^{63}_{29}\text{Cu}$				-0.212* 4	69St24
$^{63}_{29}\text{Cu}$				-0.212* 4	70Fi17
$^{65}_{29}\text{Cu}$		3/2			32R02
$^{65}_{29}\text{Cu}$			+2.6	-0.1 1	36S07
$^{65}_{29}\text{Cu}$				-0.15 10	49B61
$^{65}_{29}\text{Cu}$				-0.22 6	56K64
$^{65}_{29}\text{Cu}$				-0.19 <sup>E</sup> 4	61Fi01
$^{65}_{29}\text{Cu}$				-0.196* 4	69St24
					(67Fi02)
$^{65}_{29}\text{Cu}$				-0.161 <sup>E</sup> 3	70Fi17
				-0.196* 4	(67Fi02)
$^{64}_{30}\text{Zn}$		0 $\ddagger$			29S01
$^{64}_{30}\text{Zn}$		0 $\ddagger$			31M02
$^{66}_{30}\text{Zn}$		0 $\ddagger$			29S01
$^{66}_{30}\text{Zn}$		0 $\ddagger$			31M02
$^{67}_{30}\text{Zn}$		5/2	+0.9		37L07
$^{67}_{30}\text{Zn}$		5/2 <sup>E</sup>			48A06
$^{68}_{30}\text{Zn}$		0 $\ddagger$			29S01
$^{68}_{30}\text{Zn}$		0 $\ddagger$			31M02
$^{69}_{31}\text{Ga}$		3/2			32J04
$^{69}_{31}\text{Ga}$		3/2			33C02
$^{69}_{31}\text{Ga}$			+2.0	+1	36S10
$^{69}_{31}\text{Ga}$			$^{71}/_{69} = 1.2700$ 8		56J29

Table G: Nuclear Moments by Optical Spectroscopy — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$ or $\mu^1/\mu^2$	$Q$ or $Q^1/Q^2$	Refer.
$^{71}_{31}\text{Ga}$		3/2			32J04
$^{71}_{31}\text{Ga}$		3/2			33C02
$^{71}_{31}\text{Ga}$			+2.5	$\pm \leq 0.5$	36S10
$^{75}_{33}\text{As}$		3/2			32T01
$^{75}_{33}\text{As}$			+1.5 3	+0.3 2	36S05
$^{75}_{33}\text{As}$				+0.27* 4	58Mu08
$^{75}_{33}\text{As}$				+0.29 <sup>c</sup>	62Ko22
$^{76}_{34}\text{Se}$		0 <sup>d</sup>			33R02
$^{77}_{34}\text{Se}$		1/2 <sup>bE</sup>			54D05
$^{78}_{34}\text{Se}$		0 <sup>d</sup>			33R02
$^{78}_{34}\text{Se}$		0 <sup>bE</sup>			54D05
$^{80}_{34}\text{Se}$		0 <sup>b</sup>			34O01
$^{80}_{34}\text{Se}$		0 <sup>bE</sup>			54D05
$^{82}_{34}\text{Se}$		0 <sup>d</sup>			33R02
$^{79}_{35}\text{Br}$		3/2			30B01
$^{79}_{35}\text{Br}$		3/2			32T02
$^{81}_{35}\text{Br}$		3/2			30B01
$^{81}_{35}\text{Br}$		3/2			32T02
$^{82}_{36}\text{Kr}$		0 <sup>d</sup>			33K02
$^{83}_{36}\text{Kr}$		9/2			32M06
$^{83}_{36}\text{Kr}$			negative		33K02
$^{83}_{36}\text{Kr}$		9/2		+0.15	38K02
$^{83}_{36}\text{Kr}$		9/2 <sup>E</sup>		+0.22 <sup>E</sup> 2	55R46
$^{83}_{36}\text{Kr}$			-0.982 <sup>E</sup>	+0.17 <sup>E</sup> 5	59B08
$^{84}_{36}\text{Kr}$		0 <sup>d</sup>			33K02
$^{85}_{36}\text{Kr}$	11y	9/2	$\pm 1.005$ 2	+0.43 3	55R13
$^{85}_{36}\text{Kr}$			$^{85}/_{83} = 1.035$ 2	$^{85}/_{83} = +1.66$ 10	
$^{86}_{36}\text{Kr}$		0 <sup>d</sup>			33K02
$^{85}_{37}\text{Rb}$		5/2	$\pm 1.4$		33K01
$^{87}_{37}\text{Rb}$	47Gy	3/2	$\pm 2.8$		33K01
$^{87}_{37}\text{Rb}$	47Gy			+0.14 6	56K12
$^{86}_{38}\text{Sr}$		0 <sup>d</sup>			31F01
$^{87}_{38}\text{Sr}$		9/2	-1.1		38H05
$^{88}_{38}\text{Sr}$		0 <sup>d</sup>			31F01
$^{88}_{38}\text{Sr}$		0 <sup>d</sup>			38H05
$^{89}_{39}\text{Y}$		1/2	$\leq 0.1$		40W08
$^{89}_{39}\text{Y}$		1/2	-0.14		49C17
$^{89}_{39}\text{Y}$		1/2	negative		50K69
$^{91}_{40}\text{Zr}$		5/2 <sup>E</sup>			49A06
$^{91}_{40}\text{Zr}$			-1.9 2		55M88
$^{93}_{41}\text{Nb}$		9/2	$\approx 3.7$		34B01
$^{93}_{41}\text{Nb}$		9/2	+5.3	$\approx 0$	47M27
$^{93}_{41}\text{Nb}$				-0.25 15	58Mu04
$^{93}_{41}\text{Nb}$				-0.20 <sup>c</sup>	62Ko22
$^{92}_{42}\text{Mo}$		0 <sup>d</sup>			51A29
$^{94}_{42}\text{Mo}$		0 <sup>d</sup>			51A29
$^{95}_{42}\text{Mo}$		5/2			51A29
$^{95}_{42}\text{Mo}$		5/2	negative		54W07
$^{96}_{42}\text{Mo}$		0 <sup>d</sup>			51A29

Table G: Nuclear Moments by Optical Spectroscopy — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$ or $\mu^1/\mu^2$	$Q$ or $Q^1/Q^2$	Refer.
$^{97}_{42}\text{Mo}$		5/2			51A29
$^{97}_{42}\text{Mo}$		5/2	negative		54W07
$^{98}_{42}\text{Mo}$		0 $^\bullet$			51A29
$^{100}_{42}\text{Mo}$		0 $^\bullet$			51A29
$^{99}_{43}\text{Tc}$	210ky	9/2	+5.5 3	+0.34 17	53K49
$^{99}_{44}\text{Ru}$		5/2	-0.63 15 $\mu_{\text{eve}}(\text{Ru})=-0.66$ 2 $(\mu^{101}/\mu^{99}=\pm 1.09$ 3		55M78
$^{101}_{44}\text{Ru}$		5/2	-0.69 15		52G19) 55M78
$^{103}_{45}\text{Rh}$		1/2	-0.10 3		51K41
$^{105}_{46}\text{Pd}$		5/2	-0.57 5		52S56
$^{105}_{46}\text{Pd}$		5/2	-0.57		53B28
$^{107}_{47}\text{Ag}$		1/2	-0.10		37J01
$^{107}_{47}\text{Ag}$		1/2	-0.086		50C26
$^{107}_{47}\text{Ag}$			-0.111 <sup>E</sup> 8		51B32
$^{109}_{47}\text{Ag}$		1/2	-0.19		37J01
$^{109}_{47}\text{Ag}$		1/2	-0.159		50C26
$^{109}_{47}\text{Ag}$			-0.129 <sup>E</sup> 8		51B32
$^{110}_{48}\text{Cd}$		0 $^\bullet$			29S01
$^{111}_{48}\text{Cd}$		1/2			31S01
$^{111}_{48}\text{Cd}$		1/2	-0.62		33J02
$^{112}_{48}\text{Cd}$		0 $^\bullet$			29S01
$^{113}_{48}\text{Cd}$	>3Jy	1/2			31S01
$^{113}_{48}\text{Cd}$	>3Jy	1/2	-0.62		33J02
$^{114}_{48}\text{Cd}$		0 $^\bullet$			29S01
$^{116}_{48}\text{Cd}$		0 $^\bullet$			29S01
$^{113}_{49}\text{In}$		9/2 <sup>f</sup>	$^{113}/_{115}=1.0^f$		37B08
$^{115}_{49}\text{In}$	600Ty	9/2			33J03
$^{115}_{49}\text{In}$	600Ty	9/2			34P01
$^{115}_{49}\text{In}$	600Ty			+0.82	37B08
$^{115}_{49}\text{In}$	600Ty		+5.3	+0.8	37S11
$^{115}_{50}\text{Sn}$		1/2	-0.86		49G02
$^{116}_{50}\text{Sn}$		0 $^\bullet$			31M02
$^{117}_{50}\text{Sn}$		1/2			33S03
$^{117}_{50}\text{Sn}$		1/2	-0.89		34T01
$^{118}_{50}\text{Sn}$		0 $^\bullet$			31M02
$^{119}_{50}\text{Sn}$		1/2			33S03
$^{119}_{50}\text{Sn}$		1/2	-0.89		34T01
$^{120}_{50}\text{Sn}$		0 $^\bullet$			31M02
$^{121}_{51}\text{Sb}$		5/2			32B01
$^{121}_{51}\text{Sb}$		5/2	+4.0		34C03
$^{121}_{51}\text{Sb}$				-1.3*	53S17
$^{121}_{51}\text{Sb}$				-0.53* <sup>c</sup> 10	55M88
$^{121}_{51}\text{Sb}$				-0.50 <sup>e</sup>	62Ko22 (55M88)
$^{121}_{51}\text{Sb}$				-0.54 8	61Le13

Table G: Nuclear Moments by Optical Spectroscopy - Continued

Nucleus	$T_{1/2}$	$I$	$\mu$ or $\mu^1/\mu^2$	$Q$ or $Q^1/Q^2$	Refer.
$^{123}_{51}\text{Sb}$		7/2			32B01
$^{123}_{51}\text{Sb}$		7/2	+3.2		34C03
$^{123}_{51}\text{Sb}$				-1.2 <sup>c</sup> 2	49M48 (40T03)
$^{123}_{51}\text{Sb}$				-1.7*	53S17
$^{123}_{51}\text{Sb}$				-0.68* <sup>c</sup> 10	55M88
$^{123}_{51}\text{Sb}$				-0.69 10	61Le13
$^{123}_{52}\text{Te}$	>50Ty	1/2	$^{125}/_{123} = 1.208\ 60$		49M47
$^{123}_{52}\text{Te}$	>50Ty	1/2 <sup>E</sup>			50F08
$^{123}_{52}\text{Te}$	>50Ty		-0.6 <sup>E</sup> 2		52R05
$^{125}_{52}\text{Te}$		1/2			49M47
$^{125}_{52}\text{Te}$		1/2 <sup>E</sup>			50F08
$^{125}_{52}\text{Te}$			-0.7 <sup>E</sup> 2		52R05
$^{126}_{52}\text{Te}$		0 <sup>d</sup>			33R02
$^{128}_{52}\text{Te}$		0 <sup>d</sup>			33R02
$^{130}_{52}\text{Te}$		0 <sup>d</sup>			33R02
$^{127}_{53}\text{I}$		5/2			38M06
$^{127}_{53}\text{I}$			+2.8	-0.5	39S15
$^{127}_{53}\text{I}$				-0.67 <sup>s</sup>	58Mu10
$^{127}_{53}\text{I}$				-0.62* <sup>c</sup> 4	
$^{127}_{53}\text{I}$				-0.49 <sup>b</sup> 8	64Mu11
$^{129}_{54}\text{Xe}$		1/2			34J01
$^{129}_{54}\text{Xe}$		1/2	negative		34K02
$^{129}_{54}\text{Xe}$		1/2 <sup>E</sup>			50K09
$^{131}_{54}\text{Xe}$		3/2	positive		34K02
$^{131}_{54}\text{Xe}$		3/2 <sup>E</sup>		$\approx -0.15^E$	50K09
$^{131}_{54}\text{Xe}$			$+0.687^E\ 3$	$^{131}/^{83}\text{Kr} \approx -1$	52B57
$^{131}_{54}\text{Xe}$			$^{129}/_{131} = -1.131\ 5$	-0.12 <sup>E</sup> 2	
$^{132}_{54}\text{Xe}$		0 <sup>d</sup>			34J01
$^{134}_{54}\text{Xe}$		0 <sup>d</sup>			34J01
$^{136}_{54}\text{Xe}$		0 <sup>d</sup>			34J01
$^{133}_{55}\text{Cs}$		7/2			31K01
$^{133}_{55}\text{Cs}$			$\pm 2.40^a$		34H03
$^{133}_{55}\text{Cs}$		7/2			34J02
$^{133}_{55}\text{Cs}$			$\pm 2.52$		35S06
$^{133}_{55}\text{Cs}$				$\pm \leq 0.3$	40S09
$^{134}_{56}\text{Ba}$		0 <sup>d,E</sup>			50A51
$^{135}_{56}\text{Ba}$		3/2			32M06
$^{135}_{56}\text{Ba}$		3/2			37B09
$^{135}_{56}\text{Ba}$		3/2 <sup>E</sup>			50A51
$^{135}_{56}\text{Ba}$			$^{137}/_{135} = 1.11^E$	+0.25 <sup>E</sup> 12	60Ka24
$^{135}_{56}\text{Ba}$				+0.23 <sup>c</sup>	62Ko22
$^{135}_{56}\text{Ba}$			$^{137}/_{135} = +1.10^E\ 3$	$^{137}/_{135} = +1.6^E\ 1$	63Ja15
$^{135}_{56}\text{Ba}$				+0.13 5	64Jall
$^{135}_{56}\text{Ba}$				$\pm 0.41^i\ 4$	66Co26
$^{135}_{56}\text{Ba}$			$\pm 0.843\ 7$	$\pm 0.17\ 2$	66Co32
$^{136}_{56}\text{Ba}$		0 <sup>d</sup>			68Be60

Table G: Nuclear Moments by Optical Spectroscopy — Continued

Nucleus	$T_{1/2}$	$I$	$\mu$ or $\mu^1/\mu^2$	$Q$ or $Q^1/Q^2$	Refer.
$^{137}_{56}\text{Ba}$		3/2			32M06
$^{137}_{56}\text{Ba}$		3/2			37B09
$^{137}_{56}\text{Ba}$		3/2 <sup>E</sup>		+0.2 <sup>E</sup> 1	50A51
$^{137}_{56}\text{Ba}$				+0.21 5	60Ka24
$^{137}_{56}\text{Ba}$				$\pm 0.11$ 5	64Jall
$^{137}_{56}\text{Ba}$			$\pm 0.930$ 7		66Co26
$^{137}_{56}\text{Ba}$			$^{137}/_{135}=1.120$ 10	$(^2\text{S}_{1/2})$	66Co32
$^{137}_{56}\text{Ba}$			$^{137}/_{135}=1.144$ 54	$(^2\text{P}_{1/2})$	67Ke16
$^{137}_{56}\text{Ba}$				$\pm 0.26$ 3	68Be60
$^{138}_{56}\text{Ba}$		0*		(Using $^{137}/_{135}=1.54$ )	50A51
$^{137}_{57}\text{La}$	60ky	7/2	+2.690 6	+0.26 8	72Fi19
$^{138}_{57}\text{La}$	112Gy		+3.702 <sup>E</sup> 4	+0.51 <sup>E</sup> 9	72Fi14
$^{139}_{57}\text{La}$		7/2	$^{138}/_{139}=0.9328$ 8	$^{138}/_{139}=2.3$ 4	
$^{139}_{57}\text{La}$			+2.76		34A02
$^{139}_{57}\text{La}$				+0.3 1	40W08
$^{139}_{57}\text{La}$				+0.21* <sup>E</sup> 4	55L59
$^{139}_{57}\text{La}$					58Mu08
$^{141}_{59}\text{Pr}$		5/2			29W01
$^{141}_{59}\text{Pr}$			+3.9° 3		53B26
$^{141}_{59}\text{Pr}$					(29W01)
$^{141}_{59}\text{Pr}$			+4.0° 2		60Mu11
$^{141}_{59}\text{Pr}$			+4.09 6		65Re03
$^{143}_{60}\text{Nd}$		7/2 <sup>E</sup>	-1.1 <sup>E</sup> 1		54M91
$^{145}_{60}\text{Nd}$		7/2 <sup>E</sup>	-0.69 <sup>E</sup> 10		54M91
$^{147}_{61}\text{Pm}$	2.6y	7/2			60Ki2
$^{147}_{61}\text{Pm}$	2.6y	7/2	+2.58 7	+0.74 20	66Re04
$^{147}_{62}\text{Sm}$	0.1Ty	7/2 <sup>E</sup>	-0.76 <sup>E</sup> 8	$\pm \leq 1$	54M15
$^{149}_{62}\text{Sm}$		7/2 <sup>E</sup>	-0.64 <sup>E</sup> 6	$\pm \leq 1$	54M15
$^{151}_{63}\text{Eu}$		5/2			35S01
$^{151}_{63}\text{Eu}$			+3.4	$\approx +1.2$	38S10
$^{151}_{63}\text{Eu}$			$^{151}/_{153}=2.245$ 5		57K51
$^{151}_{63}\text{Eu}$			+3.39 3		60Kr07
$^{151}_{63}\text{Eu}$				+0.95 <sup>b</sup> 10	60Kr08
$^{151}_{63}\text{Eu}$				$\pm 1.16^{Eh}$ 8	65Mu07
$^{151}_{63}\text{Eu}$				+1.15 <sup>E</sup> 9	65Wi09
$^{151}_{63}\text{Eu}$				$(^{151}/_{153}=0.393$	60Sa23)
$^{151}_{63}\text{Eu}$				$\pm 1.12^{Eh}$ 7	68Gu02
$^{151}_{63}\text{Eu}$				$\pm 2.4^i$ 3	64Ga12
$^{151}_{63}\text{Eu}$	13y		negative	positive	70He09
$^{153}_{63}\text{Eu}$		5/2			35S01
$^{153}_{63}\text{Eu}$			+1.5	$\approx +2.5$	38S10
$^{153}_{63}\text{Eu}$			+1.51 2		60Kr07
$^{153}_{63}\text{Eu}$				+2.42 <sup>b</sup> 20	60Kr08
$^{153}_{63}\text{Eu}$				$\pm 2.92^{Eh}$ 20	65Mu07
$^{153}_{63}\text{Eu}$				+2.94 <sup>E</sup> 23	65Wi09
$^{153}_{63}\text{Eu}$				$\pm 2.85^{Eh}$ 18	68Gu02
$^{154}_{63}\text{Eu}$				positive	70He09

**Table G: Nuclear Moments by Optical Spectroscopy – Continued**

Nucleus	$T_{1/2}$	$I$	$\mu$ or $\mu^1/\mu^2$	$Q$ or $Q^1/Q^2$	Refer.
$^{155}_{64}\text{Gd}$		$3/2^E$	$-0.30^E\ 4$	$+1.1^E\ 3$	56S21
$^{155}_{64}\text{Gd}$			$-0.32^E\ 4$	$+1.6^E$	59K10
$^{157}_{64}\text{Gd}$		$3/2^E$	$-0.37^E\ 4$	$+1.0^E\ 3$	56S21
$^{157}_{64}\text{Gd}$			$-0.40^E\ 4$	$+2^E$	59K10
$^{159}_{65}\text{Tb}$		$3/2$			34S02
$^{159}_{65}\text{Tb}$			positive	$+1.26\ 12$	65Ar05
$^{159}_{65}\text{Tb}$				$+1.32\ 13$	66Ar18
$^{159}_{65}\text{Tb}$				$\pm 1.18\ 12$	70De05
$^{165}_{67}\text{Ho}$		$7/2$			35S02
$^{165}_{67}\text{Ho}$		$7/2$			57B39
$^{165}_{67}\text{Ho}$			$+3.7\ 7$		58B85
$^{165}_{67}\text{Ho}$			$+3.97^h\ 5$		68Su04
$^{169}_{69}\text{Tm}$		$1/2$			34S03
$^{169}_{69}\text{Tm}$		$1/2$	$-0.205\ 20$		55L49
$^{169}_{69}\text{Tm}$			$-0.25^e$		60Ca15
$^{171}_{70}\text{Yb}$		$1/2$			38S10
$^{171}_{70}\text{Yb}$			$+0.45$		38S11
$^{171}_{70}\text{Yb}$			$+0.49\ 6$		55K33
$^{171}_{70}\text{Yb}$			$^{171}/_{173} = -0.724\ 1$		
$^{173}_{70}\text{Yb}$		$5/2$		$+3.9\ 4$	38S10
$^{173}_{70}\text{Yb}$			$-0.65$		38S11
$^{173}_{70}\text{Yb}$		$5/2$			54K52
$^{173}_{70}\text{Yb}$			$-0.67\ 1$		55K33
$^{173}_{70}\text{Yb}$				$+2.4$	56K42
$^{173}_{70}\text{Yb}$				$+2.8^e\ 2$	62Ro26
$^{175}_{71}\text{Lu}$		$7/2$	$+1.7$	$+6.1$	35S04
$^{175}_{71}\text{Lu}$			$+2.6\ 5$	$+5.9$	36G03
$^{175}_{71}\text{Lu}$				$+5.7^e\ 3$	55K23
$^{175}_{71}\text{Lu}$				$+3.6^e\ 2$	57M96
$^{175}_{71}\text{Lu}$			$+2.0\ 2$	$+5.6\ 6$	58S134
$^{175}_{71}\text{Lu}$			$^{175}/_{176} = 0.711\ 5$	$^{175}/_{176} = 0.71\ 1$	61Bl07
$^{175}_{71}\text{Lu}$				$+5.0^e$	62Ko22
$^{175}_{71}\text{Lu}$					(55K23)
$^{175}_{71}\text{Lu}$			$\pm 2.24\ 11$		67He17
$^{176}_{71}\text{Lu}$	20Gy	$\geq 7$	$+3.8\ 7$	$+7\ 1$	39S14
$^{176}_{71}\text{Lu}$	20Gy	$6\ 1$	$+2.8\ 3$	$+8\ 1$	58S134
$^{176}_{71}\text{Lu}$	20Gy	$7^E$			59K97
$^{176}_{71}\text{Lu}$	20Gy	$7^E$	$+2.8^E\ 3$		61Bl07
$^{177}_{72}\text{Hf}$		$7/2^E$	$^{177}/_{179} = -1.276\ 8$	$^{177}/_{179} = 0.99\ 2$	56S22
$^{177}_{72}\text{Hf}$			$+0.61^E\ 3$	$+3^E\ 1$	56S53
$^{178}_{72}\text{Hf}$		$0^+$			35R01
$^{179}_{72}\text{Hf}$		$9/2^E$			56S22
$^{179}_{72}\text{Hf}$			$-0.47^E\ 3$	$+3^E\ 1$	56S53
$^{180}_{72}\text{Hf}$		$0^+$			35R01
$^{181}_{73}\text{Ta}$		$7/2$			33G02
$^{181}_{73}\text{Ta}$		$7/2$			33M01
$^{181}_{73}\text{Ta}$			$+2.1$		35G01
$^{181}_{73}\text{Ta}$				$\approx +6$	43S15

Table G: Nuclear Moments by Optical Spectroscopy - Continued

Nucleus	$T_{1/2}$	$I$	$\mu$ or $\mu^1/\mu^2$	$Q$ or $Q^1/Q^2$	Refer.
$^{181}\text{Ta}$ $^{73}\text{Ta}$			+1.9	+5.9	52B71
$^{181}\text{Ta}$ $^{73}\text{Ta}$				+4.3* 4	55K23
$^{181}\text{Ta}$ $^{73}\text{Ta}$				+2.7* <sup>c</sup> 3	57M96
$^{181}\text{Ta}$ $^{73}\text{Ta}$			+2.4 <sup>c</sup> 2		58Mu08
$^{181}\text{Ta}$ $^{73}\text{Ta}$				+3.9 <sup>c</sup>	62Ko22 (55K23)
$^{182}\text{W}$ $^{74}\text{W}$		0*			34G04
$^{183}\text{W}$ $^{74}\text{W}$		1/2			48K30
$^{183}\text{W}$ $^{74}\text{W}$		1/2 <sup>E</sup>			50F08
$^{183}\text{W}$ $^{74}\text{W}$			+0.08 2		51V06
$^{183}\text{W}$ $^{74}\text{W}$			+0.115		65Gi08
$^{184}\text{W}$ $^{74}\text{W}$		0*			34G04
$^{186}\text{W}$ $^{74}\text{W}$		0*			34G04
$^{185}\text{Re}$ $^{75}\text{Re}$		5/2			31M01
$^{185}\text{Re}$ $^{75}\text{Re}$		5/2			31Z01
$^{185}\text{Re}$ $^{75}\text{Re}$			$^{187}/_{185} = 1.0108$ 4	+2.6	37S12
$^{185}\text{Re}$ $^{75}\text{Re}$			+3.3		38S09
$^{185}\text{Re}$ $^{75}\text{Re}$				$\approx +2.9$	65Ho06
$^{185}\text{Re}$ $^{75}\text{Re}$				$\pm 2.3^E$ 9	66Ku07
$^{185}\text{Re}$ $^{75}\text{Re}$				$^{187}/_{185} = 0.95$ 4	
$^{185}\text{Re}$ $^{75}\text{Re}$				$\pm 2.36$ 50	69Kr07
$^{186}\text{Re}$ $^{75}\text{Re}$	90h		$\pm 1.38$ 45		64Wi09, 65Sc13
$^{187}\text{Re}$ $^{75}\text{Re}$	60Gy	5/2			31M01
$^{187}\text{Re}$ $^{75}\text{Re}$	60Gy	5/2			31Z01
$^{187}\text{Re}$ $^{75}\text{Re}$	60Gy			+2.6	37S12
$^{187}\text{Re}$ $^{75}\text{Re}$	60Gy		+3.3		38S09
$^{187}\text{Re}$ $^{75}\text{Re}$	60Gy			$\approx +2.9$	65Ho06
$^{187}\text{Re}$ $^{75}\text{Re}$	60Gy			$\pm 2.2^E$ 9	66Ku07
$^{187}\text{Re}$ $^{75}\text{Re}$	60Gy			$\pm 2.24$ 50	69Kr07
$^{188}\text{Re}$ $^{75}\text{Re}$	17h		$\pm 1.41$ 45		64Wi09, 65Sc13
$^{187}\text{Os}$ $^{76}\text{Os}$		1/2	positive		55M45
$^{187}\text{Os}$ $^{76}\text{Os}$		1/2	+0.0658 11		61Gu08
$^{187}\text{Os}$ $^{76}\text{Os}$			+0.0662 6		62Mu04
$^{189}\text{Os}$ $^{76}\text{Os}$		3/2	+0.70 9	+2.0 8	52M40
$^{189}\text{Os}$ $^{76}\text{Os}$		3/2			58B159
$^{189}\text{Os}$ $^{76}\text{Os}$				+0.8 <sup>c</sup>	62Ko22 (57M96)
$^{189}\text{Os}$ $^{76}\text{Os}$				+0.8* 2	62Mu04
$^{189}\text{Os}$ $^{76}\text{Os}$			+0.792		65Gi08
$^{189}\text{Os}$ $^{76}\text{Os}$				$\pm 0.91^E$ 10	68Hi04
$^{191}\text{Ir}$ $^{77}\text{Ir}$		3/2	positive		50B75
$^{191}\text{Ir}$ $^{77}\text{Ir}$		3/2	+0.16 3	+1.2 6	52M40
$^{191}\text{Ir}$ $^{77}\text{Ir}$		3/2	+0.2 1	+1.5 1	53S61
$^{193}\text{Ir}$ $^{77}\text{Ir}$		3/2			35V01
$^{193}\text{Ir}$ $^{77}\text{Ir}$		3/2	positive		50B75
$^{193}\text{Ir}$ $^{77}\text{Ir}$		3/2	+0.17 3	+1.0 5	52M40
$^{193}\text{Ir}$ $^{77}\text{Ir}$		3/2	+0.2 1	+1.5 1	53S61
$^{194}\text{Pt}$ $^{78}\text{Pt}$		0*			35F06
$^{195}\text{Pt}$ $^{78}\text{Pt}$		1/2			36J01
$^{195}\text{Pt}$ $^{78}\text{Pt}$			+0.6		36S08
$^{195}\text{Pt}$ $^{78}\text{Pt}$		1/2			37T03
$^{196}\text{Pt}$ $^{78}\text{Pt}$		0*			35F06

**Table G: Nuclear Moments by Optical Spectroscopy – Continued**

Nucleus	$T_{1/2}$	$I$	$\mu$ or $\mu^1/\mu^2$	$Q$ or $Q^1/Q^2$	Refer.
$^{197}\text{Au}$		3/2	+0.195 4		39E03
$^{197}\text{Au}$			+0.136 8		52K07
$^{197}\text{Au}$			+0.14 2	+0.56 10	53S60
$^{197}\text{Au}$				$\pm 0.58^1 1$	66Ac02
$^{197}\text{Au}$				$\pm 0.54^1 2$	66Ha43
$^{193}\text{Hg}$	6h	3/2	-0.613 20		64Kl01
$^{193}\text{Hg}$	6h	3/2		-1.8 10	66Da07
$^{193\text{m}}\text{Hg}$	11h	13/2	-1.06	+1.2 3	64To05
				$^{193\text{m}}/_{201} = 2.74 54$	
$^{193\text{m}}\text{Hg}$	11h	13/2			66Da07
$^{195}\text{Hg}$	9.5h		+0.526 5		63Kl03
$^{195}\text{Hg}$	9.5h	1/2	+0.54		64To05
$^{195\text{m}}\text{Hg}$	40h		-1.060 10	+1.5 10	63Kl03
$^{195\text{m}}\text{Hg}$	40h	13/2	-1.05	+1.3 6	64To05
				$^{195\text{m}}/_{201} = 2.81 4$	
$^{197}\text{Hg}$	65h	1/2	+0.52 1		54B92
$^{197\text{m}}\text{Hg}$	24h	13/2	-1.04 1	+1.5 3	59M82
$^{198}\text{Hg}$		0♦			31S03
$^{198}\text{Hg}$		0♦			31T01
$^{199}\text{Hg}$		1/2			31S03
$^{199}\text{Hg}$			$\pm 0.547 2$		40M10
$^{199}\text{Hg}$			+0.532		57Bl10
$^{199}\text{Hg}$			+0.51		61Ag3
$^{199}\text{Hg}$			+0.454		63Sc34
$^{199}\text{Hg}$			$\pm 0.506 3$		67Dr09
$^{200}\text{Hg}$		0♦			31S03
$^{200}\text{Hg}$		0♦			31T01
$^{201}\text{Hg}$		3/2			31S03
$^{201}\text{Hg}$		3/2	-0.6	+0.5	35S04
$^{201}\text{Hg}$			$\pm 0.607$		40M10
$^{201}\text{Hg}$				+0.47 3	59C34
$^{201}\text{Hg}$			$-0.5582 8$		60Ra27
			$^{201}/_{199} = 1.1090 7$		
$^{201}\text{Hg}$			-0.504	+0.49	63Sc34
$^{201}\text{Hg}$				+0.45	65Mu15
				+0.41*	
$^{202}\text{Hg}$		0♦			31S03
$^{202}\text{Hg}$		0♦			31T01
$^{203}\text{Hg}$	47d	5/2	+0.830 20	$\pm 0.5 8$	64Re03
$^{204}\text{Hg}$		0♦			31S03
$^{204}\text{Hg}$		0♦			31T01
$^{195}\text{Tl}$	1.2h		+1.56 4		69Go21
$^{197}\text{Tl}$	2.8h		+1.55 2		66Da15
$^{199}\text{Tl}$	7.4h		+1.57		61Hu04
$^{200}\text{Tl}$	26h		$\leq 0.15$		61Hu04
$^{201}\text{Tl}$	72h		+1.58		61Hu04
$^{202}\text{Tl}$	12d		$\leq 0.15$		61Hu04
$^{203}\text{Tl}$		1/2			31S02
$^{203}\text{Tl}$		1/2			32J02
$^{205}\text{Tl}$		1/2			31S02
$^{205}\text{Tl}$		1/2			32J02
$^{205}\text{Tl}$			$^{205}/_{203} = 1.00966 46$		37S12
$^{203}\text{Tl}$			$^{205}/_{203} = 1.0089 10$		60Od02

**Table G: Nuclear Moments by Optical Spectroscopy — Continued**

Nucleus	$T_{1/2}$	$I$	$\mu$ or $\mu^1/\mu^2$	$Q$ or $Q^1/Q^2$	Refer.
$^{206}_{82}\text{Pb}$		0 <sup>+</sup>			31M02
$^{206}_{82}\text{Pb}$		0 <sup>+</sup>			32K01
$^{207}_{82}\text{Pb}$		1/2			31M02
$^{207}_{82}\text{Pb}$		1/2			32K01
$^{208}_{82}\text{Pb}$		0 <sup>+</sup>			31M02
$^{208}_{82}\text{Pb}$		0 <sup>+</sup>			32K01
$^{206}_{83}\text{Bi}$	6.3d		+4.50 $^{206}/^{209} = +1.104$		69Ma43
$^{209}_{83}\text{Bi}$	>2Ay	9/2			28B01
$^{209}_{83}\text{Bi}$	>2Ay	9/2	+3.6	-0.4	35S04
$^{209}_{83}\text{Bi}$	>2Ay		+4.10 8		50K59
$^{209}_{83}\text{Bi}$	>2Ay			-0.37 4	67Di04
$^{209}_{83}\text{Bi}$	>2Ay			-0.379 <sup>b</sup> 15	68Ei04
$^{209}_{83}\text{Bi}$	>2Ay		+4.23 <sup>a</sup> 10	-0.4 <sup>b</sup> 1	70Cr01
$^{209}_{83}\text{Bi}$	>2Ay		+3.7 <sup>b</sup> p 5	-0.79 <sup>b</sup> to -20 <sup>p</sup>	
$^{209}_{83}\text{Bi}$	>2Ay			-0.41 4	70Ge10
$^{209}_{84}\text{Po}$	103y	1/2			55V16
$^{209}_{84}\text{Po}$	103y		+0.77 <sup>d</sup>		66Ch27
$^{227}_{89}\text{Ac}$	22y	3/2			51T19
$^{227}_{89}\text{Ac}$	22y		+1.1 1	+1.7 2	55F26
$^{229}_{90}\text{Th}$	7.3ky	5/2	+0.41 10	$\approx$ 4.6	64Eg01
$^{229}_{90}\text{Th}$	7.3ky	5/2	+0.34 7		64To02
$^{231}_{91}\text{Pa}$	34ky	3/2			34S04
$^{231}_{91}\text{Pa}$	34ky	3/2			61Ri06
$^{233}_{92}\text{U}$	162ky	5/2	positive	large	54V01
$^{233}_{92}\text{U}$	162ky	5/2	$^{233}/^{235} \approx -1.5$		55K36
$^{233}_{92}\text{U}$	162ky	5/2	$^{233}/^{235} = -1.6$ 1	$^{233}/^{235} = +0.8$ 3	56K53
$^{233}_{92}\text{U}$	162ky		positive	positive	56V27
$^{233}_{92}\text{U}$	162ky		$^{233}/^{235} = -1.6$	$^{233}/^{235} = +0.80$	
$^{233}_{92}\text{U}$	162ky	5/2		+13 5	56Z05
$^{233}_{92}\text{U}$	162ky		$\pm 0.74$	$\pm 7.9$	69Ba52, 69Be29
$^{233}_{92}\text{U}$	162ky		( $\pm 0.74$ ) (using $\mu/Q = 0.152$ 15)	$\pm 4.9$	compilers
$^{235}_{92}\text{U}$	710My	7/2			57D40)
$^{235}_{92}\text{U}$	710My	7/2			55V07
$^{235}_{92}\text{U}$	710My	7/2	$^{233}/^{235} = -1.5$	$^{233}/^{235} = +0.7$	56K53
$^{237}_{93}\text{Np}$	2.1My	5/2			57B66
$^{239}_{94}\text{Pu}$	24ky	1/2			48T08
$^{239}_{94}\text{Pu}$	24ky	1/2			54V06
$^{239}_{94}\text{Pu}$	24ky	1/2			55K36
$^{239}_{94}\text{Pu}$	24ky				55K40
$^{239}_{94}\text{Pu}$	24ky		+0.27 6		60Ch09
$^{239}_{94}\text{Pu}$	24ky		+0.21 6		62Ge11
$^{239}_{94}\text{Pu}$	24ky		$\pm 0.207^j$ 33 or $\pm 0.175^j$ 40		63Be16
$^{239}_{94}\text{Pu}$	24ky		+0.17 4		(62Ge11) (62Ko08)
$^{239}_{94}\text{Pu}$	24ky		+0.19 5		64Ba10
					66Ko24

Table G: Nuclear Moments by Optical Spectroscopy -- Continued

Nucleus	$T_{1/2}$	$I$	$\mu$ or $\mu^1/\mu^2$	$Q$ or $Q^1/Q^2$	Refer.
$^{241}_{94}\text{Pu}$	13y		$\pm 0.73$ 12 or $\pm 0.62$ 15 $(^{241}_{\text{Pu}}/^{239}_{\text{Pu}}=3.53$ 2)		63Be16
$^{241}_{94}\text{Pu}$	13y		$-0.673^{\text{E}}$ 15	+5.6 2	54B72)
$^{241}_{94}\text{Pu}$	13y		$^{241}_{\text{Pu}}/^{239}_{\text{Pu}}=-3.365$ 20		64Ch10 69Ge04
$^{241}_{95}\text{Am}$	460y	5/2			53F01
$^{241}_{95}\text{Am}$	460y	5/2		large	56T18
$^{241}_{95}\text{Am}$	460y		+1.4 3	+4.9	56M31
$^{241}_{95}\text{Am}$	460y		$^{241}_{\text{Am}}/^{243}_{\text{Am}}=1.008$		57F53
$^{243}_{95}\text{Am}$	8ky	5/2	$^{241}_{\text{Am}}/^{243}_{\text{Am}}=1.00$ 2		54C19
$^{243}_{95}\text{Am}$	8ky		+1.4 3	+4.9	56M31
$^{249}_{97}\text{Bk}$	314d	7/2			67Wo01
$^{249}_{97}\text{Bk}$	314d		$\pm 5.1$ 7	$\pm 4.7$ 10	69Wo07, 70Co34
$^{253}_{99}\text{Es}$	20d	$\geq 7/2$			68Wo07
$^{253}_{99}\text{Es}$	20d	7/2	+5.1 13	$\pm 5.1$ 10	70Wo14, 70Co34

\* Polarization or Sternheimer correction included

♦ No hyperfine structure observed

\* Polarization of resonance radiation

^ Band spectra studied

^ Recalculation of earlier data

^ Reexamined spectra of 55V16

^ Enriched sample

^  $^{113}\text{In}$ -lines apparently coincident with  $^{115}\text{In}$ -lines. Therefore, moments are believed to be the same. Lines 2% as intense as  $^{115}\text{In}$ -lines should have been observed

^ From I-spectra

^ From II-spectra

^  $Q$  obtained from deformation which was estimated from isotope shifts

^ Calculated from data on ionization potentials

^ Average value of  $Q$ 's determined for several states^ From  $\mu$ -atom hyperfine structure

^ Excited state

^ From III-spectra

^ From IV-spectra

^ LASER

^ From  $\mu$ -atom nuclear transition

**Table H: Nuclear Moments by Optical Double Resonance and Pumping Techniques**

### Introduction

In this table, data obtained by several methods involving combinations of optical spectroscopy and magnetic resonance have been collected. Some values obtained from measurements combining optical pumping and nuclear magnetic resonance are tabulated here as well as in Table E.

The possibility of using optical radiation to alter the populations of atomic states in order to study hyperfine structure by magnetic resonance techniques was first discussed in a paper by Brossel and Kastler [49Br65] and later treated more fully in a paper by Kastler [50Ka16].

Most of the optical resonance methods involve three basic features: (1) excitation of an atom from the ground state to a metastable state by resonance radiation to increase the population of certain magnetic substates by choice of appropriate frequency and polarization; (2) observation of radiation either transmitted or scattered at right angles; and (3) application of an oscillating rf or microwave magnetic field to induce a transition between substates, altering their relative populations with a subsequent change in the polarization, frequency, or intensity of the observed radiation.

A schematic diagram of a typical experimental arrangement is shown in figure 1. Light originates in a resonance lamp S. It is focused by lens L and polarized by screen P. The gas in the vessel absorbs and re-emits the resonance radiation. Photocells at the positions PC<sub>1</sub> and PC<sub>2</sub> serve to measure the transmitted or scattered light, respectively. A uniform magnetic field can be applied by a pair of Helmholtz coils and an oscillating magnetic field by coils rf.

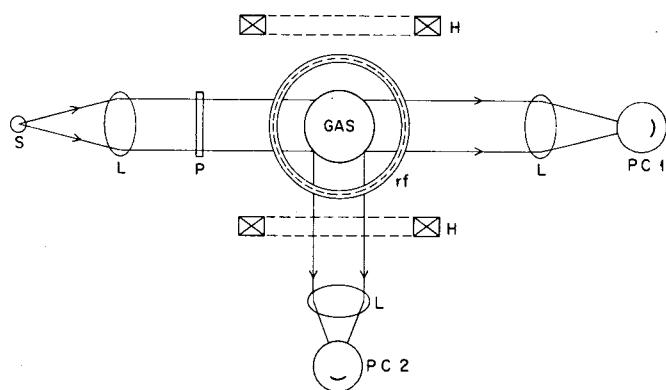


FIGURE 1. One possible arrangement of components of an optical double resonance experiment. Screen P can be used to polarize the resonance radiation from the source S. Photocells PC<sub>1</sub> and PC<sub>2</sub> respond to the transmitted and scattered light, respectively. The Helmholtz coils H produce a magnetic field along the axis of the scattered light, and the rf coils, an oscillating magnetic field perpendicular to the incident and scattered radiation.

One of the first such double resonance experiments was performed by Brossel and Bitter with Hg. The energy levels of the  $^1S_0$  and  $^3P_1$  states of the even isotopes are shown in figure 2. Absorption of incident plane-polarized,  $\pi(\Delta m_J=0)$ , resonance radiation of 2537 Å populates the  $^3P_1$ ,  $m_J=0$  substate. Application of an oscillating field at resonance frequency, inducing the  $\Delta m_J=\pm 1$  transitions, will make the circularly polarized,  $\sigma(\Delta m_J=\pm 1)$ , lines appear in the scattered radiation.

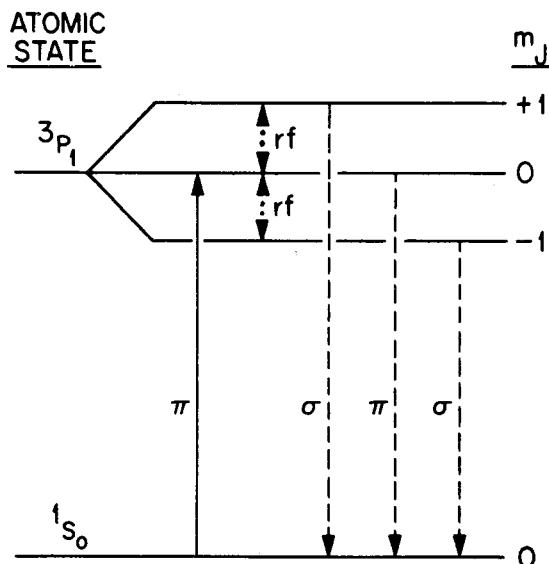


FIGURE 2. An energy level diagram for an even isotope of Hg showing transitions involved in a typical optical double resonance experiment. The levels shown are the  $^1S_0$  and  $^3P_1$  states as split by a magnetic field. The solid arrow indicates the optical absorption process while the broken arrows represent possible emission processes. Dotted arrows represent the induced rf transitions.

The optical pumping type of experiment is illustrated by the diagram for  $^{199}\text{Hg}$  in figure 3. Absorption of incident, circularly polarized,  $\sigma^+(\Delta m_F=+1)$ , radiation of the appropriate energy selectively populates the  $^3P_1$ ,  $F=1/2$ ,  $m_F=+1/2$  level which decays by  $\pi$  and  $\sigma$  emission to the  $+1/2$  and  $-1/2$  ground substates, respectively. Since the  $m_F=+1/2$  state cannot absorb the  $\sigma^+$  radiation, the  $-1/2$  state is gradually depleted and the atoms are "pumped" into the upper state. When the atoms have been oriented in this manner, the application of an rf field to induce the  $+1/2 \rightarrow -1/2$  transition in the ground state will produce an increase in the absorption and scattering of the  $\sigma^+$  light.

In a variation of the optical pumping method, a mixture of two gases or vapors is used. If one of these is optically oriented, it is found that the second gas will become oriented by collisions with the atoms of the first gas by means of a spin-exchange process. A magnetic resonance experiment per-

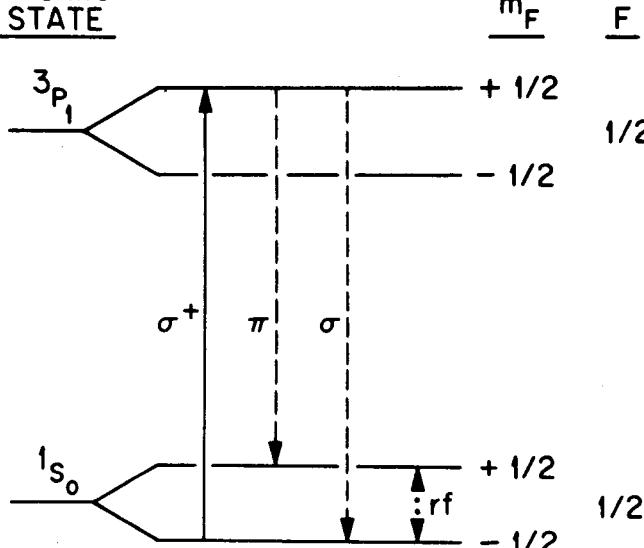
ATOMIC STATE

FIGURE 3. An energy level diagram showing the transitions involved in a typical optical pumping experiment. The levels shown are the  $^1S_0$  and  $^3P_1$ ,  $F=1/2$ , states of  $^{199}\text{Hg}$  ( $I=1/2$ ). The solid arrow represents the absorption process while the broken arrows represent the two possible emission processes. The dotted arrow represents the induced rf transition. Transitions to the  $F=3/2$  state are not shown.

formed on the second gas results in a disorientation of the first gas. The existence of the resonance for the second gas is then observed as a change in the transmission of the resonant radiation for the first gas.

In level crossing experiments, the vapor or gas is illuminated while in a homogeneous but variable magnetic field. When the magnetic field is adjusted to a value for which two levels cross, a change in the angular distribution of the resonant radiation can be observed depending on the nature of the radiation used and the  $m_F$ -values of the levels. At a field such as  $H_1$ , figure 4, the resonant radiation will be made up of the transitions CA or BA, when the levels cross or approach degeneracy (a level separation less than the natural line-width) such as at field  $H_2$ , figure 4, the scattering is from a single state, made up of a combination of the two interfering levels, and there is a change in the scattering amplitudes. Since in this type of experiment no rf or microwave radiation is needed to induce transitions between the sublevels because the energy difference of the levels is zero, it has been called a double resonance experiment at zero frequency. This technique was first used by Colegrove *et al.*

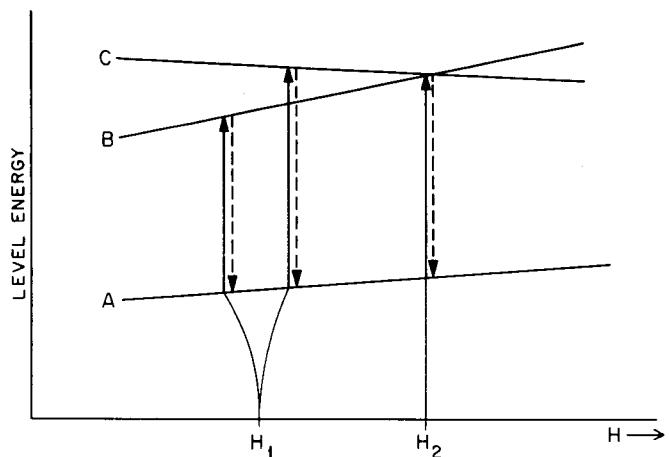


FIGURE 4. Diagram of the transitions in a level crossing experiment. Curves A, B, and C show the field dependence of the energies for the ground-state level  $A$  and two excited states  $B$  and  $C$ . Solid arrows indicate induced transitions; dashed arrows, the emitted radiation.

[59Co92] to measure the fine-structure separation of the  $^3P_1$  and  $^3P_2$  levels in helium. Additional information on the interference or coherence effects in resonance fluorescence can be found in papers by Franken [61Fr11] and by Rose and Carovillano [61Ro32].

In these experiments the interaction constants and hyperfine-structure splittings for the atomic states can be found from the energy differences (determined by the frequencies of the applied rf fields) of the hyperfine levels if transitions can be induced between them at known fields. A simple discussion of the energies of the atomic levels and the calculation of the nuclear moments from the hyperfine constants can be found in the Introduction to Table F: Nuclear Moments by Atomic and Molecular Beams.

There are many variations of double resonance techniques. In some experiments, electron bombardment is used to excite the atoms; in others, variable Zeeman scanning is used to alter the energy of the radiation emitted by the source. General discussions of optical orientation and its applications can be found in papers by Bell and Bloom [57Be36], Kopfermann [60Ko20], Dodd and Series [61Do10], Skrotskii and Izumova [61Sk3], Bitter [62Bi21], Cohen-Tannoudji and Kastler [66Co42], and Budick [67Bu26]; as well as in the papers already referred to.

The last systematic literature search for the information included in the table was in early 1971.

## Explanation of Table H

Nucleus	Chemical symbol with $Z$ - and $A$ -numbers States, other than ground states, are designated by "m" following the $A$ -number.
$T_{1/2}$	Half-life of radioactive nucleus
$I$	Nuclear spin, in units of $h/2\pi$
$\mu$	Nuclear magnetic dipole moment, in nuclear magnetons, given with diamagnetic correction. See Policies, Diamagnetic corrections, for factors used A 5% uncertainty in the diamagnetic correction is assumed.  Values of $\mu$ , which are calculated from $\Delta\nu$ - or $a$ -ratios, do not include a hyperfine-structure anomaly correction. This correction can be of the order of 0.001% to 1%. See [70FuCo].
$Q$	Nuclear electric quadrupole moment, in barns, as given by the experimenter Values marked by an asterisk, *, indicate that the experimenter has made some polarization or Sternheimer corrections in computing the moment.
Method	Symbols used to designate the various techniques are as follows:  DR Optical double resonance EI Electron impact LX Level crossing OP Optical pumping SE Spin exchange
Refer.	Reference key
Atomic State:	Atomic state for which the hyperfine-structure splitting and interaction constants are listed
$F, F'$	Total angular momentum quantum numbers which characterize hyperfine levels of the atomic state at zero magnetic field
$\Delta\nu(F, F')$	Zero-field hyperfine-structure splitting between levels of total spin $F$ and $F'$ , given without sign Values are given in MHz unless otherwise noted
Interaction Constants	Values of the interaction constants as given by the experimenter Values are given in MHz unless otherwise noted.  See Introduction to Table F for discussion of interaction constants.

Table H: Nuclear Moments by Optical Double Resonance and Pumping Techniques

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Method Refer.	Atomic State $F, F'$	$\Delta\nu(F, F')$	Interaction Constants
$^1\text{H}$					SE 62Pi04	$^2\text{S}_{1/2}: 1, 0$	1420.405738 6	
$^2\text{H}$					SE 60An13	$^2\text{S}_{1/2}: ^3/2, ^1/2$	327.384347 5	
$^2\text{H}$					OP 68Ha24	$^2\text{S}_{1/2}: ^3/2, ^1/2$	327.3843526 12	
$^2\text{H}$					SE 69La29	$^2\text{S}_{1/2}: ^3/2, ^1/2$	327.38435251 5	
$^3\text{H}$	12y				SE 62Pi04	$^2\text{S}_{1/2}: 1, 0$	1516.701464 6	
$^3\text{He}$					LX 66Ge06	$2^3\text{P}$		
$^3\text{He}$					EI 69Jo27	$3^3\text{P}: J=1, F= ^3/2 \leftrightarrow J=2, F= ^3/2$	6058	$a=-4283.5$
$^3\text{He}$					OP 70Ro16	$2^3\text{S}_1: ^3/2, ^1/2$	6739.701177 16	
$^3\text{He}^+$					SE 69Sc26	$^2\text{S}_{1/2}: 1, 0$	8665.649867 10	
$^6\text{Li}$					DR 65Ri03	$2^2\text{P}_{1/2}: ^3/2, ^1/2$	26.0 3	
$^6\text{Li}$					SE 69Wr01	$^2\text{S}_{1/2}: ^3/2, ^1/2$	228.205261 <sup>1</sup> 12	in He, Ne, Ar
$^6\text{Li}^+$					EI 69Ad11	$2^3\text{P}_1: 2, 1$	2880 5	
$^7\text{Li}$				-0.03 2	DR 65Ri03	$2^2\text{P}_{1/2}: 2, 1$	93.3 10	$a=46.65$ 50
$^7\text{Li}$					LX 67Br05	$2^2\text{P}_{3/2}$		$a=-3.40$ 23
$^7\text{Li}$				-0.039* <sup>c</sup> 26	LX 69Ly05	$2^2\text{P}_{3/2}$		$b=-0.18$ 12
$^7\text{Li}$				-0.0117*123	LX 69Is05	$3^2\text{P}_{3/2}$		
$^7\text{Li}$				+0.00073 <sup>c</sup>	SE 69Wr01	$^2\text{S}_{1/2}: 1, 0$	803.504094 <sup>1</sup> 25	in He, Ne, Ar
$^7\text{Li}$				-0.0013* <sup>c</sup>	LX 71Am02	$3^2\text{P}_{3/2}$		
$^7\text{Li}$					LX 71Ha70	$2^2\text{P}_{3/2}$ $3^2\text{P}_{3/2}$		$a=-3.01$ 5 $a=-0.98$ 4 $b=-0.09$ 1
$^8\text{Li}$	0.85s	2	$\pm 1.653^j$		SE 71Ot04	$^2\text{S}_{1/2}: ^5/2, ^3/2$	382.542 <sup>j</sup> 15	
$^{14}\text{N}$					SE 59An34	$^4\text{S}_{3/2}: ^5/2, ^3/2$ $^3/2, ^1/2$	26.12721 18	$a=+10.45091$ 7
$^{14}\text{N}$					SE 62Ho17	$^4\text{S}_{3/2}: ^5/2, ^3/2$ $^3/2, ^1/2$	15.67646 12	$b=-0.00005$ 8
$^{14}\text{N}$					SE 70Well1	$^4\text{S}$	26.127288 <sup>1</sup> 40	$a=10.450925^t$ 20
$^{14}\text{N}$							15.676390 <sup>1</sup> 40	$b=7^t$ 20Hz
$^{15}\text{N}$					SE 59An34	$^4\text{S}_{3/2}: 2, 1$	29.29136 16	$a=-14.64568$ 8
$^{15}\text{N}$					SE 62Ho17	$^4\text{S}_{3/2}: 2, 1$	29.290902 <sup>1</sup> 40	$a=14.645441^t$ 20
$^{15}\text{N}$					SE 62La1	$^4\text{S}_{3/2}: 2, 1$	29.290913 15	
$^{20}\text{Na}$	408ms	2	$\pm 0.3694^j$ 10		SE 70Bo47 71Ot04	$^2\text{S}_{1/2}: ^5/2, ^3/2$	276.6 <sup>j</sup> 3	$^{20}\text{Ne(d, )}$
$^{21}\text{Na}$	23s	3/2	$\pm 2.46^j$ 8		SE 69Ko10 71Ot04			$^{20}\text{Ne(d, )}$
$^{23}\text{Na}$				+0.10 6	DR 54S34	$^2\text{P}_{3/2}: 3, 2$ 2, 1	61 2 36.6 20	$a=19.5$ 6 $b=2.4$ 14
$^{23}\text{Na}$					OP 58A06	$^2\text{S}_{1/2}: 2, 1$	1771.6262 1	
$^{23}\text{Na}$				+0.13 4	DR 58K69	$^2\text{D}_{5/2}$		$a<0.33$
$^{23}\text{Na}$					DR 60Ar9	$^2\text{D}_{5/2}$		$a=18.5$ 6
$^{23}\text{Na}$				+0.097 13	DR 60Dol	$^3\text{P}_{3/2}$		$b=2.25$ 40, $b/a>0$
$^{23}\text{Na}$				$\pm 0.146^b$ 20	DR 66Ac01	$^3\text{P}_{3/2}$		$a=18.7$ 4
$^{23}\text{Na}$				$\pm 0.145$ 17		(using $a(\text{P}_{1/2})$ and $b$ )		$b=3.4$ 4
$^{23}\text{Na}$				$\pm 0.138^b$ 25	DR 66Ba20	$^3\text{P}_{3/2}$		$a=18.5$ <sup>+6</sup> <sub>-2</sub>
$^{23}\text{Na}$					LX 68Co21	$^3\text{P}_{3/2}$		$b=3.2$ 5
$^{23}\text{Na}$								$a=18.5$ 4
$^{23}\text{Na}$								$b=3.0$ 6

Table H: Nuclear Moments by Optical Double Resonance and Pumping Techniques – Con.

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Method Refer.	Atomic State $F, F'$	$\Delta\nu(F, F')$	Interaction Constants
$^{23}_{11}\text{Na}$				$\pm 0.121^b 14$	OP 68Ma57	$^2\text{S}_{1/2}; 2, 1$	1771.626150 <sup>p</sup> 50	$a=18.65 \ 10$
$^{23}_{11}\text{Na}$				$\pm 0.097^*$	LX 68Sc12	$^3\text{P}_{3/2}$		$b=2.82 \ 30$
				$\pm 0.114^b 12$	LX	$^4\text{P}_{3/2}$		$a=6.006 \pm 30$
				$\pm 0.095^*$				$b=0.86 \pm 9$
$^{23}_{11}\text{Na}$				$+0.124^b 15$	LX 69Ba27	$^3\text{P}_{3/2}$		$\dagger \text{Assumed } g_f = 1.334$
								$a=18.80 \pm 15$
								$b=2.9 \pm 3$
$^{23}_{11}\text{Na}$				$\pm 0.109^b 3$	DR 70Ha59	$^3\text{P}_{1/2}$		$a=94.3 \ 2$
$^{23}_{11}\text{Na}$					LX 70Ma32	$^3\text{P}_{3/2}$		$a=19.74 \ 5$
$^{23}_{11}\text{Na}$				$\pm 0.095^b 20$	LX 70Sc33	$^3\text{P}_{3/2}$		$b=3.34 \ 4$
						$^4\text{P}_{3/2}$		$a=18.9 \ 3$
								$b=2.4 \ 3$
								$a=6.2 \ 2$
								$b=1.0 \ 1$
$^{23}_{11}\text{Na}$				$\pm 0.102^c 12$	LX 71St12	$^3\text{P}_{3/2}$		$a=182.1 \ 15$
				$\pm 0.100^c 11$	(68Sc12)	$^4\text{P}_{3/2}$		$b=13.1 \ 30, b/a < 0$
$^{27}_{13}\text{Al}$					LX 66Bu15	$^2\text{D}_{5/2}$		$a=204 \pm 3$
$^{27}_{13}\text{Al}$					LX 70St26	$^2\text{D}_{5/2}$	$\dagger \text{For } g_f = 1.2$	$ b/a  \leq 0.2$
						$^2\text{D}_{3/2}$	$\dagger \text{For } g_f = 0.8$	$a=72 \pm 8$
								$ b/a  \leq 0.3$
$^{31}_{15}\text{P}$					SE 62La26	$^4\text{S}_{3/2}$		$a=+55.055691^i 8$
$^{31}_{15}\text{P}$					64Be42	$^4\text{S}_{1/2}$		expect $a < 0$ , unless exchange polarization model breaks down
$^{36}_{19}\text{K}$	245ms	2	$\pm 0.548^j 3$		SE 73Sc36			$^{36}\text{Ar}(\text{p}, )$
$^{37}_{19}\text{K}$	1.2s	3/2	$+0.20320 \ 6$		SE 71Vo03	$^2\text{S}_{1/2}; 2, 1$	240.2672 7	$^{36}\text{Ar}(\text{d}, )$
$^{39}_{19}\text{K}$			$+0.40 \ 2$	$+0.11 \ 2$	DR 57R37	$^5\text{P}_{3/2}$		$a=1.97 \ 1$
$^{39}_{19}\text{K}$					OP 60Bl15	$^2\text{S}_{1/2}; 2, 1$	461.719690 30	$b=1.7 \ 3, b/a > 0$
$^{39}_{19}\text{K}$					DR 61F011	$^5\text{P}_{1/2}$		$a=8.99 \ 15$
$^{39}_{19}\text{K}$				$\pm 0.056^p 22$	LX 67Ba64			$a=6.0 \ 1$
$^{39}_{19}\text{K}$					LX 68Sc09	$^4\text{P}_{3/2}$		$b=2.9 \ 2$
$^{39}_{19}\text{K}$						$^5\text{P}_{3/2}$		$a=1.95 \ 5$
$^{39}_{19}\text{K}$				$\pm 0.053^* 8$				$b=0.92 \ 10$
$^{39}_{19}\text{K}$				$\pm 0.057 \ 4$				$a=6.13 \ 5$
$^{39}_{19}\text{K}$				$\pm 0.0625^b 24$	LX 69Ne03	$^4\text{P}_{3/2}$		$b=2.72 \ 12$
$^{39}_{19}\text{K}$				$\pm 0.061^b 14$		$^5\text{P}_{3/2}$		$a=1.97 \ 2$
$^{39}_{19}\text{K}$								$b=0.85 \ 3$
$^{39}_{19}\text{K}$				$+0.053^* c$	LX 70Fi17	$^4\text{P}_{3/2}$		
$^{39}_{19}\text{K}$				$+0.053^* c$	(69Ne03)	$^5\text{P}_{3/2}$		
$^{39}_{19}\text{K}$				$+0.049^* c 4$	DR 71Ch61	$^6\text{S}_{1/2}; 2, 1$	45.8 2	
$^{39}_{19}\text{K}$					LX 71St12			
					(68Sc09)			
$^{40}_{19}\text{K}$	1.3Gy		$-0.093^E 25$		DR 62Bu10	$^5\text{P}_{3/2}; ^{11/2}, ^9/2$	7.68 30	$a=-2.45 \ 5$
			$-0.078^E 25$			$^{7/2}, ^5/2$	14.38 12	$b=-1.31 \ 33$
$^{40}_{19}\text{K}$	1.3Gy		$-0.07^* bE$		LX 68Ne05	$^4\text{P}_{3/2}$		$a=-7.59 \ 6$
						$^5\text{P}_{3/2}$		$b=-3.5 \ 5$
								$a=-2.45 \ 2$
								$b=-1.1 \ 2$

Table H: Nuclear Moments by Optical Double Resonance and Pumping Techniques—Con.

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Method Refer.	Atomic State $F, F'$	$\Delta\nu(F, F')$	Interaction Constants
$^{40}_{19}\text{K}$	1.3Gy			-0.068* <sup>c</sup> -0.069* <sup>c</sup>	LX 70Fil7 (68Ne05)	$4^2\text{P}_{3/2}$ $5^2\text{P}_{3/2}$		
$^{40}_{19}\text{K}$	1.3Gy			-0.067* <sup>c</sup> 10 -0.067* <sup>c</sup> 12	LX 71St12 (68Ne05)	$4^2\text{P}_{3/2}$ $5^2\text{P}_{3/2}$		
$^{41}_{19}\text{K}$				$\pm 0.0761^b$ 36	OP 60Bl15	$^2\text{S}_{1/2}; 2, 1$	254.013870 35	$a=3.40$ 8 $b=3.34$ 24
$^{41}_{19}\text{K}$				$\pm 0.0760^b$ 15	LX 69Ne03	$4^2\text{P}_{3/2}$ $5^2\text{P}_{3/2}$		$a=1.08$ 2 $b=1.06$ 4
$^{41}_{19}\text{K}$				+0.065* <sup>c</sup> $\ddagger$ +0.060* <sup>c</sup> $\ddagger$ 5	LX 70Fil7 LX 71St12			#Using $Q^{41}/Q^{39}=1.2173$ #Using $Q^{41}/Q^{39}=1.2173$
$^{43}_{20}\text{Ca}$				$<\pm 0.23$	LX 69Kl03	$^1\text{P}_1$		$a=-15.3$ 4 $b<\pm 12$
$^{53}_{24}\text{Cr}$					DR 66Bu01	$^7\text{P}_4(3d^54p)$ $^7\text{P}_3(3d^54p)$ $^7\text{P}_2(3d^54p)$ $^7\text{P}_3(3d^44s4p)$		$a=11.60$ 15 $a\leq 1.5$ 20 $a=26.16$ 10 $a=70.4$ 26
$^{55}_{25}\text{Mn}$				+0.40 2	LX 69Ha22	$z^6\text{P}_{7/2}$  $z^6\text{P}_{5/2}$  $z^6\text{P}_{3/2}$		$a=429.059^t$ 43 $b=63.86^t$ 90 $c=0.030^t$ 59 $a=467.410^t$ 13 $b=-73.46^t$ 19 $c=-0.029^t$ 26 $a=571.85$ 80 $b=11.5$ 56 $a=-72.420836^p$ 15 $b=-19031^p$ 1Hz $c=-0.7^p$ 10Hz $d<0.25$ ; $e<0.02$ Hz
$^{55}_{25}\text{Mn}$					SE 71Da36	$^6\text{S}_{5/2}$		
$^{63}_{29}\text{Cu}$			negative		LX 66Bu14	$^2\text{P}_{3/2}$		$a=195$ 2 $b=41$ 8, $b/a<0$
$^{63}_{29}\text{Cu}$				-0.25	LX 66Ne05	$^2\text{P}_{3/2}$ (using $a(^2\text{P}_{1/2})$ and b)		$a=+194.72$ 15 $b=-28.8$ 6
$^{63}_{29}\text{Cu}$					LX 67Bu10	$^4\text{P}_{3/2}$		$a=+2140.0$ 23 $b=-37.9$ 2
$^{63}_{29}\text{Cu}$				-0.315 $\ddagger$ 12 -0.235 $\ddagger$ 10	LX 68Bu16	$^2\text{P}_{3/2}$		$a=195.23$ 25 $b=28.75$ 70 $b/a<0$
$^{63}_{29}\text{Cu}$								#Used $\langle r^{-3} \rangle = 1.29 a_0^{-3}$
$^{63}_{29}\text{Cu}$				-0.211* <sup>c</sup> 4	69St24			#From D-levels, with corrections
$^{63}_{29}\text{Cu}$				-0.210* $\ddagger$ 4	LX 70Fil7			
$^{65}_{29}\text{Cu}$					LX 66Bu14	$^2\text{P}_{3/2}$		$\ddagger$ Using $Q^{63}/Q^{65}=1.0805$
$^{65}_{29}\text{Cu}$								$a=210$ 2 $b=35$ 8, $b/a<0$
$^{65}_{29}\text{Cu}$					LX 66Ne05	$^2\text{P}_{3/2}$ (using $a(^2\text{P}_{1/2})$ and b)		$a=+208.57$ 15 $b=-25.9$ 6
$^{65}_{29}\text{Cu}$				-0.22	LX 67Bu10	$^4\text{P}_{3/2}$		$a=+2292.3$ 25 $b=-35.0$ 2
$^{65}_{29}\text{Cu}$				-0.161 <sup>c</sup> 3 or -0.196* <sup>c</sup> 4	67St29 (67Fi02)	$^2\text{D}_{5/2}$ (atomic spectra)		
$^{65}_{29}\text{Cu}$				-0.228 <sup>c</sup> 5 or -0.194* <sup>c</sup> 4	(LX 67Bu10)	$^2\text{P}_{3/2}$		
$^{65}_{29}\text{Cu}$				ave -0.195* <sup>c</sup> 4 -0.194* <sup>c</sup> 4	LX 70Fil7 (66Ne05)	$4^2\text{P}_{3/2}$		

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Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Method Refer.	Atomic State $F, F'$	$\Delta\nu(F, F')$	Interaction Constants
$^{63}_{30}\text{Zn}$	38m	3/2	-0.28156*5	+0.29 <sup>t</sup> 3	DR 69La05	$^3\text{P}_1$		$a=-326.57^t 4$ $b=-34.46^t 3$ $Q^{63}/Q^{67}=1.8347 13$
$^{65}_{30}\text{Zn}$	245d	5/2	+0.7692 2	-0.024 2	DR 64By01	$^3\text{P}_1: ^7/2, ^5/2$ $^5/2, ^3/2$	1875.475 6 1334.123 6	$a=+535.163^t 2$ $b=+2.870^t 5$ $Q^{65}/Q^{67}=-0.1528 3$ $b=+2.867^t \pm 12$ $Q^{65}/Q^{67}=-0.1527 8$
$^{65}_{30}\text{Zn}$	245d			+0.18 2	LX 64La08	$^3\text{P}_1$		†Used $a$ -value of 64By01
$^{67}_{30}\text{Zn}$				DR 57Bl10	$^3\text{P}_1: ^7/2, ^5/2$ $^5/2, ^3/2$	2111.13 12 1551.54 10	$a=608.99 5$ $b=-19.37 9$	
$^{67}_{30}\text{Zn}$				DR 62Lu04	$^3\text{P}_1$		$a=609.15^t$ $b=-18.8^t$	
$^{67}_{30}\text{Zn}$				DR 64By01	$^3\text{P}_1: ^7/2, ^5/2$ $^5/2, ^3/2$	2111.300 3 1551.565 4	$a=609.086^t 2$ $b=-18.782^t 8$	
$^{67}_{30}\text{Zn}$				LX 64La08	$^3\text{P}_1$		$b=-18.770^t \pm 12$	
$^{67}_{30}\text{Zn}$		$\pm 0.87524 11$		OP 67Sp04	( $^{67}\text{Zn}$ vapor; mineral oil)		$\nu^{67}/\nu(^1\text{H})=$ 0.0625241 6	
$^{67}_{30}\text{Zn}$		$\pm 0.87524 11$		OP 67Sp11	( $^{67}\text{Zn} + ^{111}\text{Cd}$ cell)		$\nu^{67}/\nu(^{111}\text{Cd})=$ 0.295228 2	
$^{67}_{30}\text{Zn}$			+0.150 <sup>c</sup> 15	DR 69La05	$^3\text{P}_{2,1}$			
$^{85}_{37}\text{Rb}$			+0.295 20	DR 55Me07	$^6\text{P}_{3/2}: 4, 3$ 3, 2 2, 1	39.35 15 20.67 20 9.79 20	$a=8.16 6$ $b=8.40 40$	
$^{85}_{37}\text{Rb}$				DR 61Bu02	$^6\text{P}_{3/2}: 4, 3$ 3, 2 2, 1	39.275 48 20.812 61 9.824	$a=8.178 9$ $b=8.199 40$	
$^{85}_{37}\text{Rb}$			$\pm 0.298^{bE} 1$ or $\pm 0.247^{*bE}$	DR 65Sc08	$^5\text{P}_{3/2}$		$a=25.029 16$ $b=26.032 70$	
$^{85}_{37}\text{Rb}$			$\pm 0.283^{bE} 8$		$^6\text{P}_{3/2}$		$a=8.25 10$ $b=8.16 20$	
$^{85}_{37}\text{Rb}$			or $\pm 0.254^{*E}$	LX 66Bu17	(from $b$ and fine structure separation) $^6\text{P}_{3/2}$		$a=8.163 \pm 4$ $b=8.19 \pm 3$	
$^{85}_{37}\text{Rb}$		$+1.3524 2$		OP 67Ba47	$^2\text{S}_{1/2}$		†Assumed $g_F = 1.334$	
$^{85}_{37}\text{Rb}$			+0.316 7 or +0.267*6	DR 68Bu06	$^7\text{P}_{3/2}: 4, 3$	17.78 4	$g_I/g_J =$ -1.46648x10 <sup>-4</sup> 8	
$^{85}_{37}\text{Rb}$		$\pm 1.3524 2$		DR 68Fe01 OP 68Wh01	$^7\text{P}_{1/2}: 3, 2$	52.95 6	$a=3.71 1$ $b=3.68 8$	
$^{85}_{37}\text{Rb}$			+0.316 20 or +0.270*17	DR 68Zu01	$^8\text{P}_{3/2}: 4, 3$	9.55 6	$a=17.65 2$ $g_I/g_J =$ 1.4664908x10 <sup>-4</sup> 30	
$^{85}_{37}\text{Rb}$							$g^{85}/g^{87} =$ 0.2950736 7	
$^{85}_{37}\text{Rb}$							$a=1.99 \pm 2$ $b=1.98 \pm 12$	
$^{85}_{37}\text{Rb}$							†Used known $\mu$ - and $Q$ -ratios to determine $a$ and $b$ from $\Delta\nu$	
$^{85}_{37}\text{Rb}$			$\pm 0.330^{*p}$ $\pm 0.317^{*p}$	DR 68Zu03 (65Sc08)	$^5\text{P}_{3/2}$ $^6\text{P}_{3/2}$			
$^{85}_{37}\text{Rb}$			+0.260* $\pm$ 2	70Fil7			†Using $Q^{85}/Q^{87} = 2.0669$	
$^{85}_{37}\text{Rb}$			+0.263* $\pm$ 2	DR 71Ch61 71St12	$^7\text{S}_{1/2}: 3, 2$	271 15	†Using $Q^{85}/Q^{87} = 2.0669$	
$^{85}_{37}\text{Rb}$				DR 72Ch57 DR 72Gu26	$^5\text{D}_{3/2}$ $^7\text{S}_{1/2}: 3, 2$	278 <sup>p</sup> 5	$a=8^p 3$	

**Table H: Nuclear Moments by Optical Double Resonance and Pumping Techniques—Con.**

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Method Refer.	Atomic State $F, F'$	$\Delta\nu(F, F')$	Interaction Constants
$^{87}_{37}\text{Rb}$	47Gy			+0.143 10	DR 55Me07	$6^2\text{P}_{3/2}:3,2$	86.95	$a=27.63 \pm 10$ $b=4.06 \pm 20$
$^{87}_{37}\text{Rb}$	47Gy				OP 58B99	$^2\text{S}_{1/2}:2,1$	6834.682608 7	#Used known ratios $g^{87}/g^{85}=3.388$ and $b^{85}/b^{87}=2.0669$
$^{87}_{37}\text{Rb}$	47Gy				DR 61Bu02	$6^2\text{P}_{3/2}:3,2$ 2,1 1,0	87.122 43 51.418 31 23.696 97	
$^{87}_{37}\text{Rb}$	47Gy				OP 61Ca22	$^2\text{S}_{1/2}:2,1$	6834.682590 70	$a=27.707 15$ $b=4.000 39$
$^{87}_{37}\text{Rb}$	47Gy				DR 63Bu13	$5^2\text{P}_{3/2}:3,2$ 2,1 1,0	267.17 15 157.09 10 72.25 20	
$^{87}_{37}\text{Rb}$	47Gy			$\pm 0.144^{bE} 1$ or $0.120^{*bE} 4$	DR 65Sc08	$5^2\text{P}_{3/2}$ $6^2\text{P}_{3/2}$		$a=84.852 30$ $b=12.611 70$ ( $a=27.96 35$ ) $b=3.95 10$
$^{87}_{37}\text{Rb}$	47Gy			$\pm 0.123^{*E} 1$ $+0.138^E 1$ $+0.114^{*E} 1$	DR 65Zu01	(from $b$ and fine structure separation) $6^2\text{P}_{3/2}:3,2$ 2,1 1,0	87.04 3 51.46 2 23.75 6	$a=27.70 2$ $b=3.94 4$
$^{87}_{37}\text{Rb}$	47Gy				LX 66Bu17	$6^2\text{P}_{3/2}$		$a=27.61 \pm 4$ $b=3.91 \pm 7$
$^{87}_{37}\text{Rb}$	47Gy		+2.7500 5		OP 67Ba47	$^2\text{S}_{1/2}$		#Assumed $g_f=1.334$
$^{87}_{37}\text{Rb}$	47Gy			+0.147 2 or +0.124* 2	DR 68Bu06	$7^2\text{P}_{3/2}:3,2$ 2,1 1,0	39.43 2 23.43 3 10.87 4	$a=12.57 1$ $b=1.71 3$
$^{87}_{37}\text{Rb}$	47Gy		$\pm 2.7499 5$		OP 68Wh01			$g_i/g_f=$ $4.9699147 \times 10^{-4} 50$
$^{87}_{37}\text{Rb}$	47Gy			+0.153 9 or +0.131* 8	DR 68Zu01	$8^2\text{P}_{3/2}:3,2$	21.20 4	$a=6.75 \pm 3$ $b=0.96 \pm 6$
$^{87}_{37}\text{Rb}$	47Gy							#Used known $\mu$ - and $Q$ -ratios to determine $a$ and $b$ from $\Delta\nu$
$^{87}_{37}\text{Rb}$	47Gy			$\pm 0.160^{cp}$ $\pm 0.153^{cp}$	DR 68Zu03 (65Sc08)	$5^2\text{P}_{3/2}$ $6^2\text{P}_{3/2}$		
$^{87}_{37}\text{Rb}$	47Gy				70Fi17			
$^{87}_{37}\text{Rb}$	47Gy			+0.126* <sup>c</sup> 1	DR (65Sc08)	$5^2\text{P}_{3/2}$		
$^{87}_{37}\text{Rb}$	47Gy			+0.126* <sup>c</sup> 1	DR (65Zu01)	$6^2\text{P}_{3/2}$		
$^{87}_{37}\text{Rb}$	47Gy			+0.124* <sup>c</sup> 2	DR (68Bu06)	$7^2\text{P}_{3/2}$		
$^{87}_{37}\text{Rb}$	47Gy				DR 71Ch61	$7^2\text{S}_{1/2}:2,1$	565 40	
$^{87}_{37}\text{Rb}$	47Gy			+0.127* <sup>f</sup> 1	71St12			#Average value
$^{87}_{37}\text{Rb}$	47Gy			+0.127* <sup>c</sup> 1	DR (65Sc08)	$5^2\text{P}_{3/2}$		
$^{87}_{37}\text{Rb}$	47Gy			+0.127* <sup>c</sup> 1	DR (65Zu01)	$6^2\text{P}_{3/2}$		
$^{87}_{37}\text{Rb}$	47Gy			+0.123* <sup>c</sup> 2	DR (68Bu06)	$7^2\text{P}_{3/2}$		
$^{87}_{37}\text{Rb}$	47Gy			+0.129* <sup>c</sup> 8	DR (68Zu01)	$8^2\text{P}_{3/2}$		
$^{87}_{37}\text{Rb}$	47Gy				DR 72Ch57	$5^2\text{D}_{3/2}$		$a=23^p 5$
$^{87}_{37}\text{Rb}$	47Gy				DR 72Gu26	$7^2\text{S}_{1/2}:2,1$	623 <sup>p</sup> 7	
$^{87}_{38}\text{Sr}$				+‡0.36 3	DR 63Zu04	$5^3\text{P}_1:11/2,9/2$ $9/2,7/2$	1463.149 6 130.264 6	$a=-260.084 2$ $b=-35.658 6$
								#Sign from optical spectroscopy data
$^{89}_{39}\text{Y}$					LX 70Be59	$z^2\text{F}_{5/2}$ $z^2\text{F}_{7/2}$	For $g_f=0.854$ For $g_f=1.148$	$a=23.8 4$ $a=84.08 1$

Table H: Nuclear Moments by Optical Double Resonance and Pumping Techniques—Con.

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Method Refer.	Atomic State $F, F'$	$\Delta\nu(F, F')$	Interaction Constants
$^{105}_{46}\text{Pd}$					LX 68Bu04	$^3\text{P}_1$		$a=132.6$ $b/a=-1.1.5$
$^{107}_{47}\text{Ag}$					LX 66Bu18	$^2\text{P}_{3/2}$		$a=28.4$
$^{109}_{47}\text{Ag}$					LX 72Mo48	$^5\text{P}_{3/2}$		$a=36.4$
$^{105}_{48}\text{Cd}$	5.5m	5/2	-0.7385 <sup>a</sup> 2	+0.43 <sup>1</sup> 4	DR 69La06	$^3\text{P}_1$		$a=-1025.9^t 2$ $b=-103.9^t 3$
$^{107}_{48}\text{Cd}$	6.7h	5/2	-0.6155 <sup>a</sup> 8	+0.77 <sup>d</sup> 10	DR 63By02	$^3\text{P}_1$		$a=-854.2 10$ $b=-166.3$
$^{107}_{48}\text{Cd}$	6.7h		-0.61447 <sup>a</sup> 15	+0.68 <sup>d</sup> 7	LX 63Th06 69La06	$^3\text{P}_1$		$a=-853.543^t 6$ $b=-163.279^t 5$
$^{107}_{48}\text{Cd}$	6.7h		$\pm 0.61444 15$		OP 66Mc17 68Mc20	(Cd vapor; mineral oil) ( $^{107}\text{Cd} + ^{111}\text{Cd}$ cell)		$\nu/\nu(^1\text{H})=0.0437924 20$ $\nu/\nu(^{111}\text{Cd})=0.20678100 22$
$^{109}_{48}\text{Cd}$	470d	5/2	-0.8276 <sup>a</sup> 15	+0.78 10	DR 63Mc11	$^3\text{P}_1$		$a=-1148.6 20$ $b=-167.3 20$
$^{109}_{48}\text{Cd}$	470d				LX 63Th06	$^3\text{P}_1$		$a=-1148.784^t 7$ $b=-165.143^t 5$
$^{109}_{48}\text{Cd}$	470d		$\pm 0.82701 20$		OP 66Mc17 68Mc20	(Cd vapor; mineral oil) ( $^{109}\text{Cd} + ^{111}\text{Cd}$ cell)		$\nu/\nu(^1\text{H})=0.0589435 20$ $\nu/\nu(^{111}\text{Cd})=0.27832106 28$
$^{109}_{48}\text{Cd}$	470d		$\pm 0.82701 20$		OP 68Le08	( $^{111}\text{Cd} + ^{109}\text{Cd}$ cell)		$\nu^{111}/\nu^{109}=3.5929795 20$
$^{109}_{48}\text{Cd}$	470d			+0.69 <sup>e</sup> 7	69La06	$^3\text{P}_1$		
$^{111}_{48}\text{Cd}$					DR 62La24	$^3\text{P}_1; ^3/2, ^1/2$	6185.72 2	$a=-4123.81 1$
$^{111}_{48}\text{Cd}$					DR 63La12	$^3\text{P}_1$		$a=\pm 186.4$
$^{111}_{48}\text{Cd}$					LX 64Lu04	$^1\text{P}_1$		$\nu/\nu(^{199}\text{Hg})=1.1879850 5$
$^{111}_{48}\text{Cd}$			$\pm 0.59429 14$		OP 66Le21	( $^{111}\text{Cd} + ^{199}\text{Hg}$ cell)		
$^{111}_{48}\text{Cd}$			$\pm 0.59429 14$		OP 66Mc16 68Mc20	(Cd vapor; mineral oil)		$\nu/\nu(^1\text{H})=0.2117831 6$
$^{111}_{48}\text{Cd}$	49m	11/2	-1.1040 <sup>a</sup> 4	-0.85 <sup>1</sup> 9	OP 69Le10	$^5\text{P}_1$		$a$ positive
$^{111}_{48}\text{Cd}$					DR 69La06	$^3\text{P}_1$		$a=-697.1^t 2$ $b=+202.3^t 5$
$^{113}_{48}\text{Cd}$	>3Jy				DR 62La24	$^3\text{P}_1; ^3/2, ^1/2$	6470.79 2	$\nu^{113}/\nu^{111}=1.0460840 2$
$^{113}_{48}\text{Cd}$	>3Jy		$\pm 0.62167 15$		OP 67Le22	( $^{111}\text{Cd} + ^{113}\text{Cd}$ cell)		
$^{113}_{48}\text{Cd}$	>3Jy		$\pm 0.62167 15$		OP 66Mc16 68Mc20	(Cd vapor; mineral oil)		$\nu/\nu(^1\text{H})=0.221543 2$ $\nu^{113}/\nu^{111}=1.04608417 24$
$^{113}_{48}\text{Cd}$	14y	11/2	-1.0875 <sup>a</sup> 3	-0.71 <sup>1</sup> 7	DR 64By03 69La06	$^3\text{P}_1; ^{13}/2, ^{11}/2$ $^{11}/2, ^9/2$	4310.572 5 3949.625 7	$a=-686.0425^t 8$ $b=+169.047^t 9$ $\nu^{113m}/\nu^{111}=0.16623263 10$
$^{113m}_{48}\text{Cd}$	14y		-1.0867 3		OP 69Ch07	( $^{113}\text{Cd} + ^{111}\text{Cd}$ cell)		
$^{115}_{48}\text{Cd}$	2.3d	1/2	-0.6462 3		DR 64Mc06	$^3\text{P}_1$		$a=-4484.2$
$^{115}_{48}\text{Cd}$	2.3d		-0.64777 15		OP 69Ch07	( $^{115}\text{Cd} + ^{111}\text{Cd}$ cell)		$\nu^{115}/\nu^{111}=1.0900002 12$
$^{115m}_{48}\text{Cd}$	43d	11/2	-1.0424 <sup>a</sup> 10	-0.55 <sup>1</sup> 6	DR 64Mc06 69La06	$^3\text{P}_1$		$a=-657.6 6$
$^{115m}_{48}\text{Cd}$	43d		-1.0400 25		OP 69Ch07	( $^{115}\text{Cd} + ^{111}\text{Cd}$ cell)		$b=+131.6$ $\nu^{115m}/\nu^{111}=0.15908842 6$

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Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Method Refer.	Atomic State $F, F'$	$\Delta\nu(F, F')$	Interaction Constants
$^{113}_{49}\text{In}$ and $^{115}_{49}\text{In}$					LX 69Br09	$5^2\text{D}_{3/2}$ $6^2\text{D}_{3/2}$		$a = \pm 64.5 \pm 10$ $b/a = -0.59 \pm 17$ $a = \pm 72.1 \pm 3$ $b/a = -0.47 \pm 5$
$^{113}_{49}\text{In}$ and $^{115}_{49}\text{In}$					LX 70Zi06	$5^2\text{D}_{5/2}$	#Assumed $g_f = 0.8$ For $g_f = 1.2$	$a = 148.8$ $b/a \leq 0.3$ $\beta \pm 1.9 \pm 4$
$^{117}_{50}\text{Sn}$					LX 67Br24	$^3\text{P}_1^o$		$a^{117}/a^{119} = 0.9555 \pm 3$
$^{129}_{54}\text{Xe}$ $^{129}_{54}\text{Xe}$ $^{131}_{54}\text{Xe}$			$\pm 0.6913 \pm 23$		EI 69Jo26 LX 69Le02 ‡ 67Ha33	$5\text{d}[7/2]_4$ $5\text{d}[5/2]_2^o$		$a = -583.571 \pm 2$ $a = 829.5 \pm 8$
$^{131}_{55}\text{Cs}$	10d			-0.572* 10	LX 68Ac01	$6^2\text{P}_{3/2}$		$\ddagger$ “Electron-pumping.” NMR observed by change in radiation when aligned nuclei bombarded by electrons
$^{131}_{55}\text{Cs}$	10d			-0.691 9 -0.57* 1	DR 69Sc15	$7^2\text{P}_{3/2}:4,3$ 3,2 2,1	104.0 2 108 86.4 3	$a = +31.73 \pm 6$ $b = -28.63 \pm 35$
$^{131}_{55}\text{Cs}$	10d			-0.575*‡ 6 -0.583* 10 -0.570* <sup>c</sup> 8	71St12 LX (68Ac01) LX (68Ac01)	$6^2\text{P}_{3/2}$ $7^2\text{P}_{3/2}$ $6^2\text{P}_{3/2}$		‡Weighted average
$^{132}_{55}\text{Cs}$	6.2d			+0.459* 10	LX 68Ac01	$6^2\text{P}_{3/2}$		$a = +75.75 \pm 60$ $b = +73.35 \pm 160$
$^{132}_{55}\text{Cs}$	6.2d		+2.22* I	+0.570 15 +0.47* 1	DR 69Sc15	$7^2\text{P}_{3/2}:7/2, 5/2$ $5/2, 3/2$ $3/2, 1/2$	108.30 30 47.75 40 17.00 50	$a = +25.03 \pm 12$ $b = +23.60 \pm 60$
$^{132}_{55}\text{Cs}$	6.2d			+0.469*‡ 10 +0.468* <sup>c</sup> 10 +0.474* <sup>c</sup> 30	71St12 LX (68Ac01) LX (68Ac01)	$6^2\text{P}_{3/2}$ $7^2\text{P}_{3/2}$ $7^2\text{P}_{3/2}:5,4$ 4,3 3,2		‡Weighted average
$^{133}_{55}\text{Cs}$				-0.003 2	DR 55A56	$7^2\text{P}_{3/2}:5,4$ 4,3 3,2	82.85 5 66.45 5 49.90 5	$a = 16.60 \pm 1$ $b = -0.11 \pm 8$
$^{133}_{55}\text{Cs}$ $^{133}_{55}\text{Cs}$				-0.0036 13	DR 58Bu05 DR 59Bu93	$7^2\text{P}_{1/2}:4,3$ $7^2\text{P}_{3/2}:5,4$ 4,3 3,2	400.8 1 82.93 3 66.42 5 49.94 3	
$^{133}_{55}\text{Cs}$				-0.0024 <sup>b</sup> 20	DR 62Bu30	$8^2\text{P}_{3/2}:5,4$ 4,3 3,2	38.093 30 30.502 130 22.912 30	$a = 7.626 \pm 5$ $b = -0.049 \pm 42$
$^{133}_{55}\text{Cs}$					DR 64Fall	$7^2\text{P}_{3/2}:3,2$ $8^2\text{P}_{3/2}:5,4$ 4,3 3,2	49.81 <sup>b</sup> 3 37.82 5 30.32 22.85 3	$a = +7.58 \pm 1$ $b = -0.14 \pm 5$
$^{133}_{55}\text{Cs}$		$\pm 2.5780 \pm 7$			OP 68Ha01			$g_I/g_F = 1.9917398 \times 10^{-4} \pm 26$
$^{133}_{55}\text{Cs}$				-0.0028*	LX 69Sv01	$6^2\text{P}_{3/2}$	For $g_f = 1.345$	$a = 50.72 \pm 3$ $b = -0.38 \pm 18$
				-0.0032*		$7^2\text{P}_{3/2}$	For $g_f = 1.3349$	$a = 16.610 \pm 6$ $b = -0.15 \pm 3$
				-0.0030*‡ 6			‡Average	

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Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Method Refer.	Atomic State $F, F'$	$\Delta\nu(F, F')$	Interaction Constants
$^{133}_{55}\text{Cs}$					LX 69Vi03	$6^2\text{P}_{3/2}$	For $g_J=1.3341$ 3	$a=50.45$ 8 $b=-0.66$ 72
$^{133}_{55}\text{Cs}$				-0.0030* <sup>c</sup> 11	DR 71Ch61	$8^2\text{S}_{1/2}; 4, 3$	684 50	
$^{133}_{55}\text{Cs}$					DR 71St12 (59Bu93)	$7^2\text{P}_{3/2}$		
$^{134}_{55}\text{Cs}$	2.1y			+0.436 3 +0.356* 2	DR 68He07	$7^2\text{P}_{3/2}; ^{11/2}, ^9/2$ $^{9/2}, ^7/2$ $^{7/2}, ^5/2$	105.10 6 72.0 15 46.56 13	$a=+16.851$ 16 $b=+18.07$ 12
$^{134}_{55}\text{Cs}$	2.1y			+0.427 11 +0.355* 11	DR 68Kn01	$8^2\text{P}_{3/2}; ^{11/2}, ^9/2$	47.84 12	( $a=7.69$ ) $b=8.06$ 20
$^{134}_{55}\text{Cs}$	2.1y			+0.455 3	DR 69Zu04 70Fi17	$6^2\text{P}_{3/2}$		
$^{134}_{55}\text{Cs}$	2.1y			+0.360* <sup>c</sup> 3 +0.356* <sup>c</sup> 2	DR (69Zu04) DR (68He07)	$6^2\text{P}_{3/2}$ $7^2\text{P}_{3/2}$		
$^{134}_{55}\text{Cs}$	2.1y			+0.355* <sup>c</sup> 7	DR (68Kn01)	$8^2\text{P}_{3/2}$		
$^{134}_{55}\text{Cs}$	2.1y			+0.364* <sup>d</sup> 2 +0.367* <sup>c</sup> 3	71St12 (70Fi17)	$7^2\text{P}_{3/2}$	‡Weighted average	
$^{134}_{55}\text{Cs}$	2.1y			+0.361* <sup>c</sup> 3 +0.359* <sup>c</sup> 7	DR (68He07) DR (68Kn01)	$7^2\text{P}_{3/2}$ $8^2\text{P}_{3/2}$		
$^{135}_{55}\text{Cs}$	2My			+0.049 2	DR 59Bu93	$2^2\text{P}_{3/2}; 5, 4$	89.42 5	( $a=17.57$ * 1) $b=+2.19$ 9
$^{135}_{55}\text{Cs}$	2My			+0.0536*	LX 69Sv01	$6^2\text{P}_{3/2}$	For $g_J=1.345$	$a=53.64$ 4 $b=7.41$ 32
$^{135}_{55}\text{Cs}$	2My			+0.0495*		$7^2\text{P}_{3/2}$	For $g_J=1.3349$	$a=17.570$ 6 $b=2.35$ 7
$^{135}_{55}\text{Cs}$	2My			+0.052* <sup>d</sup> 5 +0.044* <sup>d</sup> 2	DR 71St12	$7^2\text{P}_{3/2}$	‡Average ‡Based on $Q^*{^{134}}$ , weighted average, and $b$ -values of 59Bu93, 68He07	
$^{137}_{55}\text{Cs}$	30y			+0.050 2	DR 59Bu93	$2^2\text{P}_{3/2}; 5, 4$	92.99 5	( $a=18.28$ * 1) $b=+2.23$ 9
$^{137}_{55}\text{Cs}$	30y			+0.0545*	LX 69Sv01	$6^2\text{P}_{3/2}$	For $g_J=1.345$	$a=55.80$ 4 $b=7.54$ 20
$^{137}_{55}\text{Cs}$	30y			+0.0499*		$7^2\text{P}_{3/2}$	For $g_J=1.3349$	$a=18.274$ 6 $b=2.37$ 4
$^{137}_{55}\text{Cs}$	30y			+0.052* <sup>d</sup> 5 +0.045* <sup>d</sup> 2	DR 71St12		‡Average ‡Based on $Q^*{^{134}}$ , weighted average, and $b$ -values of 59Bu93, 68He07	
$^{135}_{56}\text{Ba}$				+0.18 2	DR 63Zu05	$^3\text{P}_1; ^5/2, ^3/2$ $^3/2, ^1/2$	2536.94 6 1603.39 2	$a=1028.31$ 2 $b=-27.08$ 2
$^{135}_{56}\text{Ba}$		$\pm 0.83651$ 26			OP 66Ol02	$^1\text{S}_0$		$b/a=-0.02636$ 13
$^{135}_{56}\text{Ba}$					LX 68Op01	$^3\text{P}_1$		$a=3591.6706$ 3
$^{135}_{56}\text{Ba}^+$					OP 70Vo08	$6^2\text{S}_{1/2}$		
$^{137}_{56}\text{Ba}$				+0.28 3	DR 63Zu05	$^3\text{P}_1; ^5/2, ^3/2$ $^3/2, ^1/2$	2824.46 6 1819.50 2	$a=1150.59$ 2 $b=-41.61$ 2
$^{137}_{56}\text{Ba}$				$\pm 0.20$	LX 64Lu09	$^1\text{P}_1$		$a=-113.2$ 10 ( $b=58.2$ ‡)
								‡From atomic spectroscopy data

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Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Method Refer.	Atomic State $F, F'$	$\Delta\nu(F, F')$	Interaction Constants
$^{137}_{56}\text{Ba}$			$\pm 0.93573\ 28$		OP 66Ol02	$^1\text{S}_0$		$\nu^{137}/\nu^{135} =$ 1.11862 3 $b/a = -0.03621\ 13$ $a = 4018.8711\ 4$
$^{137}_{56}\text{Ba}$					LX 68Op01	$^3\text{P}_1$		
$^{137}_{56}\text{Ba}^+$					OP 70Vo08	$^6\text{S}_{1/2}$		
$^{139}_{57}\text{La}$					LX 70He26	$y^2\text{D}_{3/2}$	For $g_f = 0.802$	$a = 143.18\ 11$ $b = 1.27\ 37$
						$y^2\text{D}_{5/2}$	For $g_f = 1.186$	$a = 63.41\ 21$ $b = -13.3\ 14$
$^{139}_{57}\text{La}$					LX 70He20	$z^2\text{F}_{5/2}$	For $g_f = 0.9054$	$a = 410.8\ 10$ $b = 52.87\ 39$ $b/a = +0.1287\ 2$
						$z^2\text{F}_{7/2}$	For $g_f = 1.195$	$a = 146.11\ 25$ $b = 50.7\ 19$ $b/a = +0.347\ 8$
$^{147}_{62}\text{Sm}$					LX 69Ha60	$^5\text{F}_1(4\text{f}^55\text{d}6\text{s}^2)$ $^7\text{D}_1(4\text{f}^66\text{s}6\text{p})$		$a \sim -297^p$ $a \sim +267^p$
$^{169}_{69}\text{Tm}$					LX 69Ha60	$J = ^9/2$ $J = ^7/2$		$a = -333.9^p\ 31$ $a = -360.7^p\ 31$
$^{171}_{70}\text{Yb}$					LX 67Bu06	$^3\text{P}_1$		$a^{171}/a^{173} =$ -3.6174 2
$^{171}_{70}\text{Yb}$			$\pm 0.49188\ 20$		OP 67Ol01	$^1\text{S}_0$		$a = 3959.1\ 14$
$^{171}_{70}\text{Yb}$					LX 69Ba48	$^3\text{P}_1(6\text{s}6\text{p})$		$a^{171}/a^{173} = 3.6166\ 3$
$^{171}_{70}\text{Yb}$					DR			$a/g_f = 206.0\ 16$
$^{171}_{70}\text{Yb}$					LX 69Bu06	$^1\text{P}_1$		$a^{171}/a^{173} =$
$^{171}_{70}\text{Yb}$					LX 70Bull	$^3\text{P}_1(4\text{f}^{14}6\text{s}6\text{p})$		3.61650 5
$^{171}_{70}\text{Yb}$					DR 70Wa07	$^3\text{P}_1(4\text{f}^{13}5\text{d}6\text{s}^2)$		$a^{171}/a^{173} = 3.6329\ 5$
$^{173}_{70}\text{Yb}$			$\pm 0.67755\ 27$		OP 67Ol01	$^3\text{P}_1; ^3/2, ^1/2$ $^1\text{S}_0$	5936.739 30	$a = 3958.228\ 60$ $\mu^{173}/\mu^{171} =$ 1.37748 6
$^{173}_{70}\text{Yb}$					LX 69Ba48	$^3\text{P}_1(6\text{s}6\text{p})$		$a = -1094.7\ 6$ $b = -826.9\ 9$
$^{173}_{70}\text{Yb}$					DR			$a/g_f = 56.9\ 5$ $b/g_f = 575\ 7$
$^{173}_{70}\text{Yb}$					LX 69Bu06	$^1\text{P}_1(6\text{s}6\text{p})$		$a = -1094.35\ 3$ $b = -826.59\ 20$
$^{173}_{70}\text{Yb}$					LX 70Bull	$^3\text{P}_1(6\text{s}6\text{p})$		$a = -1094.318\ 35$ $b = -825.904\ 85$
$^{175}_{71}\text{Lu}$					DR 70Wa07	$^3\text{P}_1; ^7/2, ^5/2$ $^5/2, ^3/2$	4697.916 30 1496.414 75	
					LX 70Go15	$^2\text{D}_{3/2}$	For $g_f = 0.80$	$a = -1313.34\ 50$ $b = -455.8\ 12$
						$^2\text{F}_{5/2}$		$a/g_f = +351.864\ 56$ $b/g_f = +3444.2\ 19$
$^{181m}_{73}\text{Ta}$	11ns		$\pm 3.30 \pm 12$		LX 70Li16		Hf crystal	$\omega = 152.5\text{MHz for}$ $H = 24.2\text{kG}$
								†Observed by time differential perturbed angular correlations
$^{197}_{79}\text{Au}$			$\pm 1.04^b$ $\pm 0.57^b$		LX 69Go10	$6^2\text{P}_{3/2}$		$a = 14.0\ 5$ $b = 327.6\ 6$ $b/a = +23.4\ 8$
								‡From $b$ and fine structure

Table II: Nuclear Moments by Optical Double Resonance and Pumping Techniques—Con.

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Method Refer.	Atomic State $F, F'$	$\Delta\nu(F, F')$	Interaction Constants
$^{183}_{80}\text{Hg}$	8.8s	1/2	+0.518 <sup>j</sup> 9		OP 72Bo09 72Ot03	$^3\text{P}_1$		$a=15300\ 700$
$^{185}_{80}\text{Hg}$	50s	1/2	+0.504 <sup>j</sup> 4		OP 72Bo09 72Ot03	$^3\text{P}_1$	†Also measured by NMR/ $\beta$ AO on ground state	$a=14900\ 400$
$^{187}_{80}\text{Hg}$	2.4m	3/2	-0.586 <sup>jp</sup> 6	-0.3 <sup>lp</sup> 11	OP 72Ot03 71Bo31		‡Also measured by NMR/ $\beta$ AO on ground state	$a=-6133\ 15$
$^{193}_{80}\text{Hg}$	6h	3/2	-0.627 <sup>k</sup> 2		LX 65Re18	$^3\text{P}_1$		$(a=-6133\ 15)$
$^{193}_{80}\text{Hg}$	6h		$\pm 0.62364^p$ 34		OP 70Mo40	$6^1\text{S}_0$		$b=+477\ 182$
$^{193}_{80}\text{Hg}$	6h			-0.77 <sup>lp</sup>	OP 71Fu18	$^3\text{P}_1$		$a=-2399.69\ 6$
$^{193m}_{80}\text{Hg}$	11h		$\pm 1.063^k$ 1		LX 65Sm01	$^3\text{P}_1$		$b=-725\ 90$
$^{193m}_{80}\text{Hg}$	11h		$\pm 1.0517^p$ 6		OP 70Mo40	$6^1\text{S}_0$		$\nu/\nu^{199}=$
$^{193m}_{80}\text{Hg}$	11h		-1.0518 <sup>p</sup> 5		OP 71Re23			$0.1609411^p\ 5$
$^{195}_{80}\text{Hg}$	9.5h		$\pm 0.5381\ 3$		OP 64Wa01			$\mu^{195}/\mu^{199}=$
$^{195}_{80}\text{Hg}$	9.5h		$\pm 0.5389^k\ 3$		LX 65Sm01	$^3\text{P}_1$		$1.070356\ 66$
$^{195m}_{80}\text{Hg}$	40h	13/2	$\pm 1.049^k$ 1		LX 65Sm01	$^3\text{P}_1$		$a=15813.46\ 23$
$^{195m}_{80}\text{Hg}$	40h		$\pm 1.0380^p$ 5		OP 70Mo40	$6^1\text{S}_0$		$a^{195}/a^{199}=$
$^{195m}_{80}\text{Hg}$	40h		-1.0381 <sup>p</sup> 5		OP 71Re23			$1.071927\ 15$
$^{197}_{80}\text{Hg}$	65h	1/2	$\pm 0.525^k$ 1		DR 59M81	$^3\text{P}_1$		$a=-2368.04\ 8$
$^{197}_{80}\text{Hg}$	65h		$\pm 0.5243^k\ 3$		LX 61Hi16	$^3\text{P}_1$		$b=-782.45\ 86$
$^{197}_{80}\text{Hg}$	65h		$\pm 0.5241\ 2$		OP 62Wa07			$\nu/\nu^{199}=$
$^{197}_{80}\text{Hg}$	65h		$\pm 0.5245^k\ 3$		DR 63St15	$^3\text{P}_1: ^3/2, ^1/2$	23086.37 10	$0.1588454\ 4$
$^{197m}_{80}\text{Hg}$	24h		-1.032 <sup>k</sup> 8		DR 61Br17	$^3\text{P}_1: ^{15}/2, ^{13}/2$ $^{13}/2, ^{11}/2$	(18248 <sup>j</sup> 11) 14234.86 9	$a=15405\ 30$ $a=15387.1\ 53$ $\mu^{197}/\mu^{199}=$ $1.042479\ 15$
$^{197m}_{80}\text{Hg}$	24h		-1.0316 <sup>k</sup> 10	±1.61 13	DR 61Hi16	$^3\text{P}_1: ^{15}/2, ^{13}/2$ $^{13}/2, ^{11}/2$	18246 14 14236 20	$a=15392.66^f\ 15$ $a=-2328.89\ 84$ $b=-902.9\ 54$
$^{197m}_{80}\text{Hg}$	24h		$\pm 1.0211^p$ 6		OP 70Mo40			‡Calculated from data of Hirsch
$^{197m}_{80}\text{Hg}$	24h		-1.0212 <sup>p</sup> 5		OP 71Re23			$a=-2328.8\ 17$
$^{199}_{80}\text{Hg}$					DR 59P33	$6^3\text{F}_4: ^9/2, ^7/2$	5800 100	$b=-901\ 13$
$^{199}_{80}\text{Hg}$			+0.50270 24		OP 61Ca21	$^1\text{S}_0$		$\nu/\nu^{199}=$
$^{199}_{80}\text{Hg}$					LX 61Hi16	$^3\text{P}_1$		$0.1562657\ 3$
$^{199}_{80}\text{Hg}$					DR 63St15	$^3\text{P}_1: ^3/2, ^1/2$	22128.56 10	$\mu^{199}/\mu(^1\text{H})=$ +0.1782706 3
$^{199}_{80}\text{Hg}$					OP 71Re23			$a=14750.7\ 50$
$^{199m}_{80}\text{Hg}$	43m	13/2	-1.00832 <sup>p</sup> 5		LX 71Re24	$6^3\text{P}_1$		$a=14754.04^f\ 14$
$^{199m}_{80}\text{Hg}$	43m				OP 72Ot03			$\nu/\nu^{199}=$
$^{199m}_{80}\text{Hg}$	43m			+2.0 <sup>jp</sup> 13	DR 58S40	$^3\text{P}_1$		$0.1542921\ 5$
$^{201}_{80}\text{Hg}$				±0.58 18	DR 59P33	$6^3\text{F}_4: ^{11}/2, ^9/2$ $^{9}/2, ^7/2$ $^{7}/2, ^5/2$	2860 50 2340 50 1820 50	$a=-2298.7^p\ \ddagger\ 4$
$^{201}_{80}\text{Hg}$								‡Assumed $b=-900\ 300$
								$a=5441\ 15$
								$b=-35\ 2$

Table H: Nuclear Moments by Optical Double Resonance and Pumping Techniques—Con.

Nucleus	$T_{1/2}$	$I$	$\mu$	$Q$	Method Refer.	Atomic State $F, F'$	$\Delta\nu(F, F')$	Interaction Constants
$^{201}_{80}\text{Hg}$			-0.55671 27		OP 61Ca21	$^1\text{S}_0$		$\mu^{201}/\mu(^1\text{H}) = -0.1974198 9$
$^{201}_{80}\text{Hg}$					DR 61Ko5	$^3\text{P}_1: ^5/2, ^3/2$ $^3/2, ^1/2$	13986.557 8 7551.613 13	$a = -5454.569 3$ $b = -280.107 5$
$^{201}_{80}\text{Hg}$			-0.55670 27		DR 63Le18			$\mu^{201}/\mu^{199} = -1.1074164 5$
$^{203}_{80}\text{Hg}$	47d		$\pm 0.8436 4$		OP 70Ki05	$^6\text{S}_0$		$\nu^{201}/\nu = 1.09984 18$
$^{203}_{80}\text{Hg}$	47d		+0.850* 9	+0.40 <sup>1</sup> 4	LX 70Re14	$^3\text{P}_1$		$a = 4991.35 3$ $b = -249.2 3$
$^{205}_{80}\text{Hg}$	5.5m	1/2	+0.5968 <sup>ip</sup> 5		OP 72Ot03			
$^{203}_{81}\text{Tl}$ and $^{205}_{81}\text{Tl}$					LX 69Zi02	$^6\text{D}_{3/2}$	For $g_J = 0.8$	$a = 42.2$ $\beta \ddagger = 0.12 1$ $a/\beta > 0$
$^{203}_{81}\text{Tl}$ and $^{205}_{81}\text{Tl}$					LX 70Zi07	$^7\text{D}_{3/2}$	For $g_J = 0.8$	$a = 55.1$ $\beta \ddagger = 0.20 4$ $a/\beta > 0$
								‡Stark coefficient in MHz/(kV/cm) <sup>2</sup>
$^{207}_{82}\text{Pb}$			$\pm 0.5783 7$		LX 66Sa09	$^3\text{P}_1$		$a = 8811.17$
$^{207}_{82}\text{Pb}$			$\pm 0.57810 \ddagger 29$		OP 69Gi03	$^3\text{P}_0$		$\nu/\nu_p = 0.20502 22$
$^{207}_{82}\text{Pb}$					OP 69Gi04	$^3\text{P}_0$		$\nu/\nu(^{199}\text{Hg}) = 1.14960 4$
								‡Using $\mu_{unc}^{199} = +0.497856 5$ , 61Ca21
								Large discrepancy with NMR-value may be due to large interaction of $^3\text{P}_1$ -state with $^3\text{P}_0$ -state

\* Polarization or Sternheimer correction included

\* Calculated from the  $\Delta\nu$ - or  $a$ -ratio for two isotopesb Calculated from  $b/a$ 

c Recalculation of earlier data

d No diamagnetic correction added. Unsure if authors already corrected for it

e Enriched sample used

f Corrected for second order perturbations of neighboring levels

g Extrapolated to zero intensity

h Extrapolated to zero power

i Extrapolated to zero pressure

j Resonance observed by depolarization of polarized nuclei

k Calculated using  $a^{199} = 14754.0 1$  [63St15] and the uncorrected  $\mu(^{199}\text{Hg}) = +0.497856 5$  from Cagnac [61Ca21]l Calculated from the  $b$ -ratio for two isotopes

m Metastable or excited state

p Preliminary value from meeting abstract, thesis, private communication, etc.

**Table J: Nuclear Moments by Nuclear Orientation, Perturbed Angular Correlation and Nuclear Specific Heat Measurements**

### Introduction

Nuclear moment values obtained by nuclear orientation, perturbed angular correlation and nuclear specific heat measurements are collected in this table. The last systematic literature search for the data included was done in early 1972. A brief review of the techniques follows.

#### Nuclear Orientation:

If a sample of nuclei is unoriented, the spatial distribution of radiation emitted by the sample is isotropic. If the nuclei can be oriented in some manner, the radiation is frequently no longer isotropic. The actual distribution depends on the type of radiation ( $\alpha$ ,  $\beta$ , or  $\gamma$ 's), the degree of orientation of the nuclei, the spins of the initial and final states as well as the angular momentum,  $L$ , carried off by the radiation. The term "oriented" is used to indicate that the  $2I+1$  nuclear magnetic substates,  $m_z$ , are unequally populated. If the pairs of substates with the same  $m_z$  but opposite signs,  $+m_z$  and  $-m_z$ , have equal populations, the nuclei are said to be aligned. If they have unequal populations, the nuclei are said to be polarized.

The angular distribution of the radiation emitted by an ensemble of nuclei, with spin  $I_o$ , can be written in terms of Legendre polynomials as:

$$W(\theta) = \sum_{k=0}^{k_{\max}} B_k F_k P_k(\cos \theta) \quad (1)$$

where  $k_{\max}$  is the smaller of  $2I_o$  and  $2L$ .  $\theta$  is the angle between some fixed axis,  $z$ , and the direction of propagation of the radiation. The  $B_k$  are orientation parameters which depend on the relative populations of the substates of  $I_o$ . The  $F_k$  are angular correlation functions which depend on the spins  $I_o$ ,  $I_f$  and on  $L$  of the transition. For radiation other than  $\gamma$ 's, "particle parameters",  $b_k$ , must be included in the expansion. For  $\alpha$ 's and unpolarized  $\gamma$ 's, in general, only even  $k$  occur. Odd  $k$  can be present for  $\beta$ -decay and polarized  $\gamma$ 's.

To be oriented at low temperature, the nuclei must have a lifetime long enough so that they can be incorporated in a suitable material. Most  $\gamma$ -emitting states, with the exception of a few isomers, have very short lifetimes. However, many radioactive nuclei which decay by  $\alpha$ - or  $\beta$ -emission or K-capture have long lifetimes and the angular distribution of the  $\gamma$  or  $\gamma$ 's following the decay can be measured. The degree of orientation of the  $\gamma$ -emitting state can be calculated from that of the oriented nucleus if the

spins of the preceding states and the angular momenta carried off by and mixtures of all preceding radiations are known. Such calculations assume that the intermediate state half-lives are short so that there are no perturbations acting to change the populations of the states. If this is true, the angular distribution in (1) can be replaced by:

$$W(\theta) = \sum_{k=0}^{k_{\max}} B_k(I_o, T) [\prod_a U_k^{(a)}(I_a, L_a, I_{a+1})] \times F_k(I_n, L_n, I_f) P_k(\cos \theta) \quad (2)$$

where each  $U_k^{(a)}$  is a function of the nuclear spins and angular momentum for the  $a^{\text{th}}$  unobserved transition preceding the observed one.  $k_{\max}$  is the smaller of  $2I_o$ ,  $2I_a$ ,  $2I_n$ ,  $2L_a$ ,  $2L_n$ . If any of the spins  $I_o$  through  $I_n$  is 0 or  $1/2$ , the angular distribution becomes isotropic.

For an assembly of atoms at thermal equilibrium, the population of any level,  $m$ , is proportional to the  $\exp[-E_m/kT]$ . If the differences in the energies of the levels are small with respect to  $kT$ , the populations will be approximately equal. However, if the separation between levels can be made the order of  $kT$ , either by increasing the interaction energy and/or decreasing  $T$ , the nuclei can be oriented. For a discussion of several methods for producing oriented nuclei at low temperatures, see [65Da10] or [65De31].

Originally paramagnetic salts, incorporating the nucleus under investigation, were cooled to very low temperatures by adiabatic demagnetization. The nuclei were oriented by the hyperfine interaction of external or internal fields with the nuclear or electronic moments. The "brute force" method of orientation making use of the direct interaction of the nuclear magnetic moment was originally suggested by Gorter [34Go01] as a means of possibly further lowering temperatures. More recently, orientation experiments have been done on nuclei imbedded as dilute impurities in ferromagnetic metals and antiferromagnetic crystals, taking advantage of the very large fields present at the impurity sites. These materials are usually cooled by thermal contact with paramagnetic salts at very low temperatures.

The material chosen for cooling must fit certain requirements. It must have a large specific heat so that it will not warm up rapidly after being cooled. It must be able to be cooled to a very low temperature and it must be possible to determine its temperature. A large number of the earlier orientation experiments were done on nuclei in the following classes of salts since many had been thoroughly investigated and their properties well known; see [61Hu20]:

Tutton salts:  $M''M'_2(XO_4)_2 \cdot 6H_2O$

Rare-earth ethyl sulphates:  $M'''(C_2H_5SO_4)_3 \cdot 9H_2O$

Double nitrates:  $M_2'''M_3''(NO_3)_{12} \cdot 24H_2O$

Fluosilicates:  $M''SiF_6 \cdot 6H_2O$

Two of these, cerium magnesium nitrate, CMN, and neodymium ethyl sulphate, NES, have been used for very many moment determinations. Around 1965, it was observed by the Berkeley group [65Fr19], [66Bl17] that the temperature dependence of  $\gamma$ -anisotropies of CMN and NES showed sharp discontinuities below  $\sim 0.003^{\circ}K$ . They felt these could only be satisfactorily explained by assuming that the earlier temperature scales for these materials were based on properties that were not sensitive enough to the temperature below  $\sim 0.003^{\circ}K$ . It appeared that the temperatures actually reached were much lower than those given by the magnetic temperature relationship. For this reason, very low temperature measurements done with these salts prior to 1965 are suspect.

In order to determine nuclear moments, a material, whose low temperature properties are known, is chosen for the nuclear environment. It is cooled, the nuclei oriented, and the  $\gamma$ -intensity or the  $\gamma$ -anisotropy,  $\epsilon$ ,

$$\epsilon = [W(90^\circ) - W(0^\circ)]/W(90^\circ) \quad (3)$$

is measured as a function of the temperature. The resulting curve is then fit by adjusting the values of the interaction constants on which the orientation parameters,  $B_k$ , depend. The anisotropy or intensity also depends upon the values chosen for the spins of all nuclear levels involved and on the angular momenta of the transitions through the  $U_k$ - and  $F_k$ -terms in (2). In order to determine the degree of orientation of the nuclei, the temperature at the nucleus must be known. Frequently a reference nucleus, such as  $^{60}Co$  or  $^{54}Mn$  with well-known orientation parameters, can be incorporated into the sample to act as a thermometer. The distribution of the reference nuclei should be similar to that of the nuclei under consideration to minimize differences due to local warming.

The advantages of measuring nuclear moments by nuclear orientation stem from the fact that one is counting a single transition, rather than coincidences, so that sufficient data can be obtained in reasonable times with very dilute samples. However, the nucleus must have a lifetime of the order of hours and a sufficiently large  $\mu$  or  $Q$  in order to be oriented. Temperatures below  $\sim 0.01^{\circ}K$  are necessary.

The accuracy of such measurements is not very great. The magnetic moment can be determined to about 10%. A more recent development combines NMR techniques with low temperature orientation and leads to moments which can be determined to

about 0.1%. In these experiments the NMR frequency is observed by the destruction of the orientation at resonance. A short review of this technique can be found in [68Sh25].

Measurements of the  $\gamma$ -anisotropy do not yield the sign of the magnetic moment, but the sign can be determined from a measurement of the  $\gamma$ -ray circular polarization or  $\beta$ -asymmetry since these depend on the polarization of the nucleus and involve the odd  $k$  terms in (1) as well as the even ones.

The major difficulties encountered in orientation experiments have to do with:

- 1) the knowledge of the temperature at the nuclei. There can be heat leaks, local warm-up due to radiation, and difficulties in measuring the temperatures accurately;
- 2) the presence of perturbations acting on the nuclei during the finite lifetimes of the intermediate levels. These cause changes in the relative populations of the levels.

For more complete discussions of nuclear orientation and the measurement of nuclear moments using oriented nuclei, see [57Bl04], [65Da10] or [65De31]. *Nuclear Orientation* edited by M. E. Rose [63Ro33] is a handy collection of early journal papers and some review articles on this subject. Discussions of more recent techniques and problems can be found in the proceedings of several recent conferences on hyperfine interactions, for example, see [71St46].

#### Nuclear Specific Heat:

A few moments have been determined from measurements of the specific heat at very low temperatures. The specific heat,  $C_p$ , of a system can be expressed as a sum:

$$C_p = C_L + C_E + C_M + C_N \quad (4)$$

$C_L$  is the lattice contribution to the specific heat. For temperatures well below the Debye temperature, i.e.  $T < \theta/50$ , it is given by:  $C_L = AT^3$ , where  $A$  is a constant.  $C_E$ , the electronic specific heat, the contribution due to the conduction electrons, is given by  $C_E = \gamma T$ , a relation which holds up to about  $1000^{\circ}K$ .  $C_M$ , the magnetic specific heat which is due to the exchange interaction of the local electronic spins of neighboring ions, does not contribute to the total specific heat at very low temperatures of the order of  $1^{\circ}K$ . The nuclear specific heat,  $C_N$ , depends on the energies of the  $2I+1$  levels of the different orientations of the nucleus with respect to the effective fields. From statistical mechanics it can be shown that:

$$C_N = [R/(kT)^2] \left( \sum_{ij} [H_i^2 - H_i H_j] \exp[-(H_i + H_j)/kT] \right) \times \left( \sum_{ij} \exp[-(H_i + H_j)/kT] \right)^{-1} \quad (5)$$

where  $H_i$ ,  $H_j$  are the energies of levels  $i$ ,  $j$ . In terms of effective magnetic and quadrupole interaction constants,  $A'$  and  $P'$ , the energy can be written as:

$$H_m = A'm + P'[m^2 - I(I+1)/3] \quad (6)$$

for  $m = -I, -I+1, \dots, +I$ .

To carry out such experiments, samples of ferromagnetic or antiferromagnetic metals or alloys are thermally isolated as well as possible after being cooled to temperatures below 1°K. The samples are then heated electrically and the temperature measured. If the specific heat can be measured over a range of about 0.4 to 4°K, it may be possible to obtain  $C_N$  and the interaction constants from the temperature dependence of the specific heat. Above about 1°K,  $C_N$  can be neglected and  $C_L$  and  $C_E$  separated by plotting  $C_p/T$  vs  $T^2$ . The contributions of  $C_L$  and  $C_E$  can be subtracted from the data below 1°K to determine  $C_N$ , which dominates in this region. These measurements require samples of great purity and very reliable thermometry. Since gram quantities are needed and only average properties for the natural isotopic abundances of the elements are measured, this method has not been used for moment measurements except for the few cases of the monoisotopic rare earths.

A review of the determination of interaction constants from nuclear specific heat measurements can be found in [67Lo12].

#### Perturbed Angular Correlation:

In the absence of perturbing electric or magnetic fields, the angular correlation of two successive radiations can be expressed in terms of the Legendre polynomials, as:

$$W(\theta) = \sum_{k=0}^{k_{\max}} A_{kk} P_k(\cos \theta) \quad (7)$$

where  $\theta$  is the angle between them and the  $A_{kj}$  are coefficients which depend on the angular momentum,  $L_j$ , carried off by the  $j$ th transition, on the spins of the nuclear levels involved,  $I_i$ ,  $I_n$  (see figure 1) and on the kind of radiation,  $\alpha$ ,  $\beta$ ,  $\gamma$ , or  $e^-$  [53Bi10].  $k_{\max}$  is the minimum of  $2I$ ,  $2L_1$ ,  $2L_2$ . In a simplified description, the observation of the first radiation chooses a particular direction in space or quantization axis. The relative populations of the sublevels of the intermediate state depend on the type of radiation

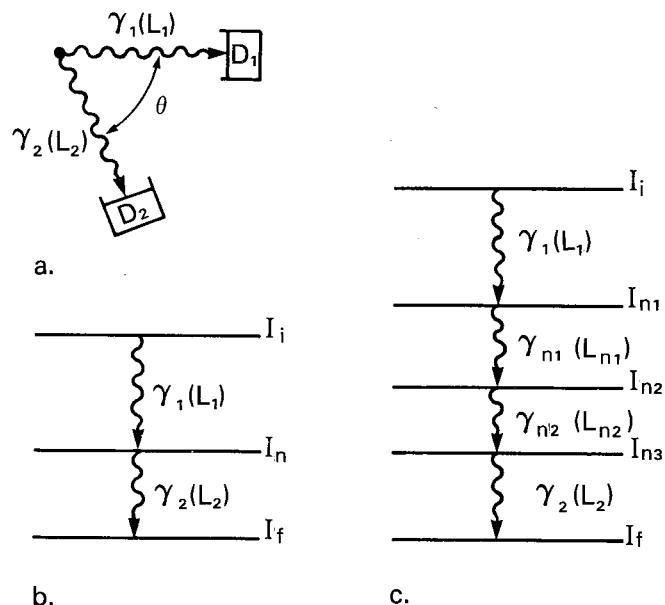


FIGURE 1a. Scheme for the detection of the correlation of  $\gamma_1$  and  $\gamma_2$ .  $D_1$  and  $D_2$  are the detectors for  $\gamma_1$  and  $\gamma_2$ , respectively.  
 b. Decay scheme for the emission of two successive  $\gamma$ 's.  
 c. Decay scheme for the emission of  $\gamma$ 's in a multiple cascade.

The  $L_j$  represent the angular momenta carried off in each transition; the  $I_j$ , the spins of the nuclear levels.

and the spins of the levels,  $I_i$ ,  $I_n$ . The angular distribution of the second radiation with respect to the first is then a function of the angular momentum carried off,  $L_2$ , the spin of the level,  $I_n$ , and the population distribution in the intermediate state, which remains unchanged if, during the lifetime,  $\tau$ , of the intermediate state, there have been no perturbing interactions. For the observation of the correlation of  $\gamma_1$  and  $\gamma_2$  in a multiple cascade (see figure 1c), a more general form of (7) can be written:

$$W(\theta) = \sum_{k=0}^{k_{\max}} A_{kk} P_k(\cos \theta) \quad \text{or} \quad = 1 + \sum_{N=2}^{k_{\max}} b_N \cos N\theta \quad (8)$$

where the  $A_{kk}$  are products of functions of 1) the level spins, the angular momentum and the mixing ratio for each of the observed radiations and 2) the level spins for the intervening unobserved radiations in the cascade.  $k_{\max}$  is the smallest of  $2L_1$ ,  $2L_2$  and the  $2I$  in the cascade. The  $b_N$  are simple algebraic functions of the  $A_{kk}$  in this alternate way of expressing the correlation.

The possibility of perturbing the angular correlation by magnetic fields was first pointed out by Hamilton [40Ha20]. The effect of hyperfine structure and of applied magnetic fields on the angular correlation was originally calculated by Goertzel [46Go05] and

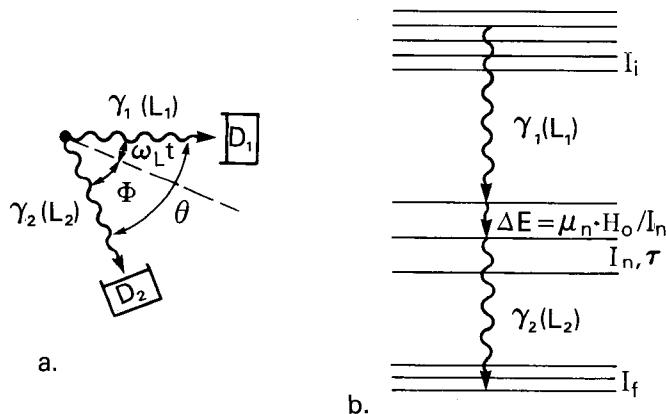


FIGURE 2a. Scheme for the observation of the correlation of two  $\gamma$ 's in a transverse magnetic field. During the time  $t$ , between the emission of  $\gamma_1$  and  $\gamma_2$ , the nucleus precesses through the angle  $\omega_L t$ . Therefore, at any given angle  $\theta$ , the unperturbed correlation of  $\theta - \omega_L t$  is observed.  $D_1$  and  $D_2$  are the detectors for  $\gamma_1$  and  $\gamma_2$ , respectively. b. Decay scheme for the emission of two  $\gamma$ 's perturbed by the application of an external field,  $H_0$ , which causes a transition between the substates of the intermediate state during its lifetime,  $\tau$ .

looked for by Brady and Deutsch [50Br27], but the primitive counting techniques available at that time made it impossible to observe any perturbation. In a semiclassical description, the interactions of the nuclear moments with perturbing magnetic or electric fields cause the nuclei to precess during the lifetime of the intermediate state. This results in a change in the angular distribution of the second radiation with respect to the first. A schematic representation of this is shown in figure 2. The nucleus decays to a particular sublevel of the intermediate state by the emission of the first radiation. The magnetic or electric interaction with the perturbing fields causes a transition between the sublevels of the intermediate state which is then followed by the emission of the second radiation. In the presence of perturbing fields, the angular correlation can be expressed in terms of the unperturbed correlation coefficients and the spherical harmonics for each radiation:

$$W(k_1, k_2, t) = \sum_{k_1 k_2 \mu_1 \mu_2} A_{k_1}(1) A_{k_2}(2) G(k_1 k_2 \mu_1 \mu_2 t) \times Y_{k_1}^{\mu_1}(\Omega_1) Y_{k_2}^{\mu_2}(\Omega_2) \quad (9)$$

For the exact form of the attenuation factors,  $G(k_1 k_2 \mu_1 \mu_2 t)$ , for many kinds of static and time-dependent perturbations, including mixed electric and magnetic interactions, see [65Fr20] or [64St29], which are essentially equivalent papers, [64Al32], or [53Ab15]. A few specific examples, for frequently encountered situations, are given below.

In the absence of any other perturbations, the application of a static magnetic field causes, in general, both an attenuation of the angular

correlation as well as a rotation of the observed pattern. For the special case in which the external field,  $H$ , is perpendicular to the direction of emission of the observed  $\gamma$ 's, the perturbed angular correlation, PAC, has a particularly simple form:

$$\begin{aligned} W_{\perp}(\theta, t, H) &= \sum_{k=0}^{k_{\max}} A_{kk} P_k [\cos(\theta - \omega_L t)] \\ \text{or} \\ &= 1 + \sum_{N=2}^{k_{\max}} b_N \cos N(\theta - \omega_L t), \end{aligned} \quad (10)$$

where  $\omega_L = 2\pi g \mu_N H / \hbar$  is the Larmor precessional frequency, the  $A_{kk}$  or  $b_N$  are the unperturbed correlation functions and  $t$  is the time between the observation of the two gammas. It is assumed that the detectors can distinguish between the gammas. If the direction of the magnetic field at the nucleus is known, the sign of the magnetic moment can be determined from the direction of rotation of the correlation. If additional perturbations are present, these must be taken into account. In order to reduce the effect of any time-dependent quadrupole interactions, dilute solutions or liquid metals are frequently employed. In such sources, if the correlation time,  $\tau_c$ , is small compared to the observation time or lifetime and if  $\omega_L \tau_c \ll 1$ , the effect of such perturbations is to multiply each term in (10) by an attenuation factor,  $G_k = \exp(-\lambda_k t)$ , where  $\lambda_k$  is the relaxation constant for the interaction.

For static quadrupole interactions, the attenuation factors of equation (9) cannot be expanded in terms of a single parameter ' $k$ ' as was possible in the magnetic case. However, for an axially symmetric field, they can be expressed in terms of  $\omega_o$ , the smallest non-vanishing quadrupole frequency, where  $\omega_o = 3\omega_Q$  or  $6\omega_Q$ , for  $I$  integer or half-integer\*, respectively, with  $\omega_Q = -2\pi(eQ/4hI) \times (2I-1)^{-1}$ . Then

$$G(k_1, k_2, \mu_1, \mu_2, t) = \sum_{n=0}^{n_{\max}} g_n(k_1, k_2, \mu) \cos n\omega_o t \quad (11)$$

with  $n = |m^2 - m'^2|$  for integer  $I$  and  $(1/2)|m^2 - m'^2|*$  for half-integer  $I$ . For a non-vanishing quadrupole perturbation,  $k_{\max}$  must be greater than or equal to 4.

For randomly-oriented static fields, for example, for powdered crystalline sources, the angular correlation can be written as:

$$W(\theta) = 1 + \sum_k G_{kk} A_{kk} P_k (\cos \theta) \quad (12)$$

\*Note these corrections to the corresponding expressions given in [65Fr20] or [64St29].

The form of the correlation does not change; however, the coefficients of the  $P_k(\cos\theta)$  are reduced. Since there are always some nuclei in the sample aligned along the direction of observation of one of the counters, there is a lower limit to the attenuation factors. For axially-symmetric fields, this lower limit or "hard-core" value is  $G_{kk} = 1/(2k + 1)$ . If the perturbing fields are randomly-fluctuating, the correlation can be destroyed.

The many kinds of PAC experiments for the measurement of magnetic moments can be divided into two major classifications: (1) the time-integrated methods, with observation times longer than the lifetime of the intermediate state, which yield values of  $\omega_L\tau$ ; and (2) the differential methods which determine  $\omega_L$  directly. Because of the great variety of these experiments, only a brief discussion of a few representative techniques will be given. For more detailed information on the many modifications and variations, the reader is referred to the review articles by Frauenfelder [65Fr20], or Grodzins [68Gr31].

From equation (10), it can be seen that a measurement of the correlation as a function of delay time for a constant value of  $H$ , or as a function of  $H$  at a constant delay time yields  $\omega_L$ , and therefore  $g$ , directly from the period of oscillation,  $T$ , of the correlation. A more sensitive measure of the period can be obtained by observing the correlation at some fixed angle for field up ( $W_\perp \uparrow$ ) and down ( $W_\perp \downarrow$ ) and plotting the ratio,  $R = W_\perp \uparrow / W_\perp \downarrow$ , as a function of  $t$  or  $H$ , respectively. If the resolution time,  $\tau_0$ , is small,  $\tau_0 \ll \tau$  and  $\tau_0 \ll T$ ,  $g$  may be obtained from the period of oscillation of  $R$  through the relation:

$$T = h/2g\mu_N H \quad (13)$$

$R$  is independent of the decay of the source and the period of  $R$  is not greatly affected by small time-dependent perturbations.

If  $k_{\max} = 4$ , the ratio,

$$r = 2(W_\perp \uparrow - W_\perp \downarrow) / (W_\perp \uparrow + W_\perp \downarrow) \quad (14)$$

at  $\theta = 3\pi/4$ , is also an oscillating function of the delay time of the form:  $A(\sin 2\omega_L t)/(B - C \cos 4\omega_L t)$  with period also given by (13).  $A$ ,  $B$ , and  $C$  represent functions of the  $A_{kk}$ . The presence of small time-dependent perturbations does not much alter the period of  $r$  from which  $g$  is calculated, although it does cause the amplitudes of the oscillations to decrease with an increase in delay time.

Differential techniques have been used to determine moments of states with lifetimes of the order of  $10^{-3}$  to  $10^{-9}$  seconds.

For time-integrated measurements, IPAC, the expression for the correlation is obtained by averaging equation (9) over the observation time (zero

delay time and infinite resolving time). Equation (10) then becomes:

$$W_\perp(\theta, H) = 1 + \sum_{N=2}^{k_{\max}} (b_N/[1 + (N\omega_L\tau)^2]^{1/2}) \times \cos N(\theta + \Delta\theta) \quad (15)$$

where  $\Delta\theta = (1/N) \tan^{-1}(N\omega_L\tau)$ . In this case, both an attenuation and a rotation of the correlation are observed. For small  $\omega_L\tau$ ,  $\Delta\theta \sim \omega_L\tau$ . In the presence of time-dependent quadrupole perturbations, the precession angle,  $N\omega_L\tau$ , and the correlation coefficients are both reduced by an attenuation factor, which, for  $\omega_L\tau \ll 1$ , is  $(G_{kk})_{ave} = 1/(1 + \lambda_{kk}\tau)$ .

In the early experiments, the entire correlation was obtained with and without an external field and the rotation, from which  $g$  can be calculated, was measured. As in the case of DPAC, more sensitive measurements for small rotations,  $\omega_L\tau \ll 1$ , can be made by measuring the coincidences at a constant angle for field up and field down. The ratio,

$$r(\infty) = 2[W_\perp(\uparrow) - W_\perp(\downarrow)] / [W_\perp(\uparrow) + W_\perp(\downarrow)], \quad (16)$$

is approximately  $4b_2(G_2)_{ave}\omega_L\tau$  for  $k_{\max} = 2$  and  $\theta = 3\pi/4$  or  $7\pi/4$ . The product  $b_2(G_2)_{ave}$  can be determined from the zero field correlation for the particular source used. A measurement of  $r$  then yields  $\omega_L\tau$ . Another useful ratio for the determination of  $g$ , again for  $\omega_L\tau \ll 1$ , is:

$$y(\infty) = [W_\perp(\pi/4) - W_\perp(3\pi/4)] / [W_\perp(\pi) - W_\perp(\pi/2)] \quad (17)$$

which is approximately  $2(G_2)_{ave}\omega_L\tau$  if  $b_4 \ll b_2$ . The slope of  $y$  vs  $H$  yields  $g$  if  $(G_2)_{ave}$  is known.

If the detectors, in  $\gamma\gamma$  measurements, cannot distinguish between the two gammas, only an attenuation is observed and equation (15) becomes:

$$W_\perp(\theta, H) = 1 + \sum_N (b_N/[1 + (N\omega_L\tau)^2]) \cos N\theta; \quad (18)$$

that is, the unperturbed correlation is attenuated by the factor  $[1 + (N\omega_L\tau)^2]^{-1}$ .

All integral methods yield the product  $\omega_L\tau$ ; therefore, the value obtained for the magnetic moment depends upon knowledge of the lifetime of the intermediate state. The values of  $\mu$  appearing in the accompanying table have been corrected for newer values of the lifetimes. However, the uncertainty in the lifetime has not been taken into account since most of the measurements are not accurate enough to warrant such treatment.

Integral measurements have been made for states with lifetimes of the order of  $10^{-7}$  to about  $10^{-12}$  seconds. The upper limit is set by the number of accidental coincidences which are accepted; the lower, by the magnetic fields available.

Since other unknown perturbations may contribute to the attenuation of the correlation, attenuation measurements are much less reliable for the determination of moments than those of the rotation of the correlation. Further, the sign cannot be ascertained from the attenuation factors.

In order to extend PAC measurements to a wider range of states than are accessible with normal radioactive decay products, nuclear reactions and scattering experiments with pulsed beams have been used. The reaction orients the nucleus by preferentially populating sublevels of the excited state and the perturbed angular distribution, PAD, of the gamma-decay can be measured by integral or differential methods, using pulse repetition times greater than the lifetime of the state. Such techniques have been used for measurements on states with lifetimes of the order of milliseconds to nanoseconds.

The recent stroboscopic measurements [70Ch05] make use of a pulsed beam with a repetition time smaller than the lifetime of the intermediate state,  $T_o \ll \tau$ . For such an experiment, the counting rate at a time  $t$  after the pulse burst is given by the sum of intensities of the contributions of all previous bursts. For the observation of the gamma in a transverse field, neglecting other perturbations, the intensity can be written as:

$$\begin{aligned} I(\gamma) &= \sum_{a=0}^{\infty} \exp[-(t + aT_o)/\tau] \sum_{k \text{ even}} [1 + A_k(1)A_k(2) P_k(\cos[\theta - \omega_L(t+aT_o)])] \\ &\equiv e^{-t/\tau} \sum_{k \text{ even}} \frac{b_k [\cos k(\theta - \omega_L t) - \exp[-T_o/\tau] \cos k(\theta - \omega_L(t-T_o))]}{[1 - 2\exp[-T_o/\tau] \cos k\omega_L T_o - \exp[-2T_o/\tau]]} \end{aligned} \quad (19)$$

Here  $T_o$  is the repetition time of the beam pulses;  $t$ , the delay time or observation time of the gamma after the pulse-burst; and the  $A_k$  are the correlation functions for the reaction product and the gamma. The contributions of different bursts will add constructively if the condition:

$$k\omega_L T_o = 2n\pi \text{ for some } n = 1, 2, \dots \quad (20)$$

is satisfied. Thus, for a given  $T_o$ , the counting rate will show resonances at values of  $H_o = nh/kg\mu_N T_o$ . For  $k_{\max}=2$  and values of  $H=H_o$ , the maximum or minimum of the correlation may be observed by choosing  $\theta_o$  and  $t_o$  to satisfy the relation:

$k(\theta_o - \omega_L t_o) = 2m\pi$  or  $(2m-1)\pi$ , respectively,

for  $m = 0, 1, 2, \dots$

The stroboscopic method has been used for states with lifetimes from milliseconds to about 0.1 microseconds.

To measure the moments of very short-lived states by PAD, nuclei have been implanted by Coulomb excitation (IMPAC) or imbedded in ferromagnetic and paramagnetic materials to make use of the very large internal fields known to exist at impurity sites. One of the major difficulties in these experiments is knowledge of the magnetic fields perturbing the nucleus. The past history of the source and its treatment can cause wide variations in the fields present. The recoil of the nucleus can displace it from its regular position in the lattice. If the lifetimes are very short, of the order of picoseconds, the transient fields acting on the nucleus as it is slowing down become important. Some estimate of these effects can be made using states with "known" moments. For the particular case of the magnetic moments of the Pt and Os excited states, measured using Ir-Fe alloys, great variations have been observed which cannot be explained, suggesting that the Ir-Fe alloys are unsuitable for moment measurements [71Kil3].

Perturbed angular correlation has been a useful technique for the measurement of moments of a very large number of states which are not accessible by standard resonance or spectroscopic methods, that is,

those states with lifetimes between about  $10^{-3}$  and  $10^{-12}$  seconds. However, there are several problems associated with this kind of experiment. For a non-isotropic angular correlation, the states involved must have spins greater than or equal to 1. This means that, in studying magnetic moments, the quadrupole interaction cannot easily be eliminated as is possible in many spectroscopic or resonance experiments where atomic states with  $J = 1/2$  or 0 are used. However, by proper choice of sources, it is often possible to reduce the quadrupole interactions. Since PAC experiments involve the decay of radioactive nuclei, the atom can be left in highly excited states. This is especially true following K-capture or alpha-decay. If the nuclear lifetime is very short, the environment may not have reached equilibrium

before the emission of the second radiation and the perturbations acting on the nucleus are not completely known.

In PAC experiments, as with all determinations of  $\mu$ , the magnetic field at the nucleus must be known. For many of the measurements, the values of  $\mu$  are determined only to about 5–10% and therefore the diamagnetic and Knight-shift corrections, which are less than 1–2% even for the heaviest atoms, are not important. However, for transition elements, the rare-earths, and the transuranic elements, paramagnetic corrections must be made for the large fields caused by the unfilled inner electron-shells. A table of correction factors,  $\beta$ , for rare-earth ions for temperatures of 50° to 2000°K can be found in [64Gu06].

In an actual angular correlation experiment the

time-resolution, counter-efficiencies, geometry, accidental coincidences and the effects of other coincidences which may have been present, must all be taken into account in the evaluation of the moments. A discussion of the treatment of the raw data appears in Frauenfelder and Steffen's paper [65Fr20], p1188.

General discussions of perturbed angular correlations can be found in the many papers already cited. There are also several reviews on particular methods in Hyperfine Interactions [67Fr15]. Discussions of some of the newer techniques and problems can be found in the proceedings of several of the recent international conferences, for example, those at Asilomar, 1967 [68Ma56]; Delft, 1970 [71Va39]; Rehovot, 1970 [71Go39]; and Osaka, 1972 [72Pr21].

### Explanation of Table J

Nucleus	Chemical symbol with $Z$ - and $A$ -number
Level	Energy, in keV, of the level for which information is given Ground state levels are indicated by gs.
$T_{1/2}$	Half-life of the level The value quoted is taken from Table of Nuclear Half-lives [68Ma49], Nuclear Data Sheets (through Volume B5), Table of Isotopes [67LeHo], or it is the value used in the referenced article.
$I$	Nuclear spin, in units of $h/2\pi$ , used to obtain $\mu$ from the deduced $g$ -value Values enclosed in ( )'s have been determined by resonance or spectroscopic techniques.  Values enclosed in [ ]'s have been inferred from decay characteristics
$\mu$	Nuclear magnetic dipole moment, in nuclear magnetons The values of $\mu$ obtained by Integral Perturbed Angular Correlations or Attenuated Angular Correlations, which are derived from the measurement of $\omega\tau$ , have been corrected to the value of $T_{1/2}$ quoted unless otherwise indicated by an "a".  In general, values of $\mu$ determined by these techniques are not accurate enough to warrant the application of a diamagnetic correction. Those marked by "d" have had a diamagnetic correction included.
$Q$	Nuclear electric quadrupole moment, in barns, as given by the experimenter Those values marked by an asterisk, *, indicate that the experimenter has made some polarization or Sternheimer correction in computing the moment.
Refer.	Reference key number

Method	Codes used to designate the specific techniques are:
	AAC attenuation of the angular correlation
	BAO, BAP $\beta$ -asymmetry from oriented, polarized nuclei
	CDPAC constant delay perturbed angular correlation
	DAAC time differential attenuated angular correlation
	DPAC, DPAD time differential perturbed angular correlation, distribution
	GAO, GAP $\gamma$ -anisotropy from oriented, polarized nuclei
	IMPAC perturbed angular correlation following implantation
	IPAC, IPAD integral perturbed angular correlation, distribution
	NMR nuclear magnetic resonance
	NRF nuclear resonance fluorescence
	PAC, PAD perturbed angular correlation, distribution
	SpHt nuclear specific heat
	Strob stroboscopic perturbed angular correlation
	SE spin exchange
	$\alpha$ AO $\alpha$ -anisotropy from oriented nuclei
Measured Quantity	Measured quantities from which the moments are derived Units quoted are as given or as determined from graphs or data presented. There has been a confusion in the units quoted for precessional frequencies in many papers (an interchange of Hz and rad./s). We have tried to correct these, but we include a footnote to the author's quoted unit.
Environment and Comments	Nature of materials used; magnetic fields (external or internal); assumptions made; comments If there are a series of values for a respective series of conditions, the values and conditions are set off by similar punctuation.  The notation $(185\gamma)(89\gamma)$ represents coincidences between the 185keV $\gamma$ and the 89keV $\gamma$ .

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^8_3\text{Li}$	gs	0.85s	(2)	$\pm 1.6532^d 8$		59Co68	BAP-NMR	$\nu=3.413$ 1 MHz	$^7\text{LiF}(\text{polarized } n, \gamma)$ $H_o=5418$ 1 G
$^8_3\text{Li}$	gs	0.85s	(2)	positive		62Co08	BAP-NMR		$^7\text{LiF}(\text{polarized } n, \gamma)$
$^8_3\text{Li}$	gs	0.85s	(2)	$\pm 1.6532^d 8$		67Gu14	BAP-NMR	$\ddagger$ Compared Zeeman level transition rates for two senses of circularly polarized rf fields.	$^7\text{LiF}(\text{polarized } n, \gamma)$ $H_o=3.2649$ 4kG
$^8_3\text{Li}$	gs	0.85s	(2)	$\pm 1.65362^p 22,$ $\pm 1.65288^p 20,$ $\pm 1.65270^p 30$		71Ha67	BAP-NMR		$^7\text{Li}(\text{d,p})$ recoils in Au,Pt,Pd foils
$^8_3\text{Li}$	gs	0.85s	2	$\pm 1.653$		71Ot04	BAP-SE		
$^8_5\text{B}$	gs	770ms	[2]	$\pm 1.03551^{dp} 25$		72Mi19	BAP-NMR		$^6\text{Li}(^3\text{He},n)$ recoils in Pt foil.
$^{10}_5\text{B}$	720	690ps	[1]	$+0.63$ 12		72Av01	IPAC		$^9\text{Be}$ on Au(p, ); $H_o=17.6$ kG
$^{12}_5\text{B}$	gs	20.4ms	(1)	$+1.003$ 1		67Su03 68Su05	BAP-NMR	$\nu_o/\nu_p \ddagger =$ 1.79641 32, 1.79637 39; 1.79510 25, 1.79526 29; 1.79639 22	$^{11}\text{B}(\text{d,p})$ recoils in Cu;Pt;Au foils. $H_o$ measured by proton resonance. $\mu$ (uncorrected for $\sigma + K$ ) $=1.00337$ 15; 1.00270 11; 1.00337 12
								‡Includes correction of 25.6 ppm for proton resonance in $\text{H}_2\text{O}$	
$^{12}_5\text{B}$	gs	20.4ms	(1)	$\pm 0.976$ 31		68Pf03 70Wi17	DPAD		$^{11}\text{B}(\text{d,p})$ polarized $^{12}\text{B}$ recoils in Au, Pd; $H_o$ 8.24 to 15.95G
$^{12}_5\text{B}$	gs	20.4ms	1	$\pm 0.017 \ddagger 2$		70Su04 71Mi06	BAP-NMR	$eqQ=154$ 16 kHz; 49 5kHz $Q^{12}/Q^{11}=\pm 0.42$ 4	$\text{TiB}_2$ ; $\text{ZrB}_2$
$^{12}_5\text{B}$	gs	20.4ms	(1)	$+1.00285^{+15}_{-14}$		70Wi17	BAP-NMR	$\ddagger$ Used $Q^{11}=+0.04065$ 26 (70Ne21) $\mu=1.00336$ 8; 1.00324 6; 1.00253 5; 1.00261 6	$^{11}\text{B}(\text{d,p})$ recoils in Au;Cu; Pd;Pt; values uncorrected for Knight shift; $H_o$ measured by proton resonance.
				$+0.030$ 8				‡Includes Knight shift estimated from spin relaxation times.	
								$eqQ=59$ 15kHz	$^{11}\text{B}(\text{d,p})$ recoils in Be foils; compared with values for Be; used $\gamma_a(B^{3+})=-0.145$
$^{12}_5\text{B}$	gs	20.4ms	(1)	$\approx 0.0346^p$		71Wi28	BAP-NMR	$eqQ=54.9$ 6kHz	$^{12}\text{B}$ implanted in Be single crystal.
$^{13}_5\text{B}$	gs	19ms	[3/2]	$\pm 3.17712 \ddagger 51$		71Wi09	BAP-NMR	$\nu/\nu_p=0.379104$ 25	$^{11}\text{B}(\text{t,p})$ recoils in Au, Pt, Pd foils.
$^{13}_5\text{B}$	gs	19ms	[3/2]	$\pm 0.08$		72Ha68	BAP-NMR	$\ddagger$ Includes estimate of Knight shift from $^{12}\text{B}$ $Q^{12}/Q^{13}=0.358^p 8$	$^{11}\text{B}(\text{d,p})$ and ( $\text{t,p}$ ) recoils in Mg crystal
								$eqQ^{13}=130$ 2kHz $eqQ^{12}=46.5$ 5kHz	
$^{12}_7\text{N}$	gs	12ms	(1)	$+0.4571$ 1		68Su05 67Su09	BAP-NMR	$\nu/\nu_p \ddagger =0.081817$ 23; 0.081850 23; 0.081869 23; 0.081836 13	$^{10}\text{B}(^3\text{He},n)$ recoils in Al; Cu; Pt; $H_o$ measured by proton resonance; $\mu$ (uncorrected for $\sigma$ and $K$ )= 0.45699 13; 0.45723 10; 0.45709 7
								‡Includes correction of 25.6 ppm for proton resonance in $\text{H}_2\text{O}$	
$^{12}_7\text{N}$	gs	12ms	1‡			71Mi06	BAP-NMR		$^{10}\text{B}(^3\text{He},n)$ recoils in Nb, Ta
								‡From observed quadrupole spectra	

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat — Continued**

Nucleus	Level	$T_{1/2}$	I	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{14}_7\text{N}$	5830	12.4ps	[3]	$1.5 \leq  \mu  \leq 2.55^p$		72Be60	PAC		$^{12}\text{C}(\text{He},\text{p})$ recoils in He gas or vacuum; used $H_{1s,\text{calc}}=57.3\text{MG}$
$^{18}_8\text{O}$	1980	3.3ps	[2]	$0.40 <  \mu  < 0.72$		72Go06	AAC		$^{12}\text{C}(\text{O}^{7+},\text{O}')$ ; $H_{\text{calc}}=85.5\text{MG}$ at oxygen nucleus
$^{17}_9\text{F}$	gs	66s	[5/2]	$\pm 4.7224^d 12$		66Su01	BAP— NMR	$\nu/\nu_p = 0.33797,$ $0.33804$	$\text{O}(\text{d},\text{n})$ recoils in $\text{CaF}_2$ ; $H_o \approx 5\text{kG}$
$^{18}_9\text{F}$	1125	153ns	[5]	+2.840 65		67Po09	DPAD	$\omega = 16.6 \text{ Mr/s}$ for all cascades	( $\text{SiO}$ on $\text{Cu}$ ) $(\text{He},\text{p})$ ; $H_o = 6.1 \text{ 6kG}$
$^{18}_9\text{F}$	1125	153ns	[5]	+2.860 30		67Sc09	DPAD		( $\text{CaO}$ on $\text{Au}$ ) $(\text{He},\text{p})$ ; $H_o = 15.71\text{kG}$
$^{19}_9\text{F}$	197	89ms	[5/2]	+3.69 4		61Fr07	DPAD		$\text{LiF}$ ; $\text{CaF}_2$ ; $\text{NaF}(\text{p},\text{p}')$
$^{19}_9\text{F}$	197	89ns	[5/2]	+3.59 2	$\pm 0.11 \ 2$	64Su01	DPAD	$\nu_o = 12.4 \text{ 6MHz}$	$\text{ClF}(\text{p},\text{p}')$
$^{19}_9\text{F}$	197	89ns	[5/2]	+3.59 2		67Br14	DPAD		( $\text{CaF}_2$ on $\text{Cu}$ ) $(\text{p},\text{p}')$ ; $(\alpha,\alpha')$ ; $H_o = 10465\text{G}$ measured by proton resonance
$^{19}_9\text{F}$	197	89ns	[5/2]	$\pm 3.605 \ 8$		69Bl18	DPAD	$\omega_p/\omega = 3.874 \ 8$	Thick $\text{CaF}_2$ target ( $\text{p},\text{p}'$ ); $H_o = 2.5$ to $18.8\text{kG}$
$^{20}_9\text{F}$	gs	11s	[2]	+2.094 <sup>d</sup> 2		63Ts01	BAP— NMR		$\text{CaF}_2$ crystal(polarized n, ); $H_o$ measured by proton resonance
$^{20}_9\text{F}$	gs	11s	[2]	$\pm 2.0935^d 9$		67Gu14	BAP— NMR	$\nu = 2.1820 \text{ 7MHz}$	$\text{CaF}_2$ crystal (polarized n, ) $H_o = 2.7358 \text{ 4kG}$
$^{20}_9\text{F}$	gs	11.2s	[2]		$\pm 0.064 \ 20$	73Ac03	BAP— NMR	$eqQ = \pm 5.77 \text{ 2MHz}$ $Q/Q^{19}(197\text{keV}) = \pm 0.108 \ 4$	$\text{MgF}_2$ crystal(polarized n, ); $H_o = 4.35\text{kG}$
$^{19}_{10}\text{Ne}$	238	17.7ns	[5/2]	-0.740 8		69Bl02	DPAD	$\omega/\omega(^{19}\text{F}-197) = -0.2054 \ 15$	$\text{CaF}_2$ (pulsed p,n); $H_o \approx 34\text{kG}$
$^{20}_{11}\text{Na}$	gs	408ms	2	$\pm 0.3694^p 10$		71Ot04	BAP— SE		$^{20}\text{Ne}(\text{d},2\text{n})$
$^{22}_{11}\text{Na}$	583	243ns	[1]	+0.535 10		70Bo47			$^{210}\text{Po}$ in 30N HF; $H_o = 6111 \text{ 30G}$
$^{22}_{11}\text{Na}$	583	243ns	[1]	+0.555 17		66Su07	DPAD	$\omega = 15.65 \text{ 25Mr/s}$	( $\text{CaF}_2$ on $\text{Cu}$ ) $(\alpha,\text{n})$
$^{29}_{15}\text{P}$	gs	4.2s	[1/2]	$\pm 1.2349^d 3$		71Su13	BAP— NMR	$\mu = 1.23374 \ 9;$ $1.23356 \ 3$	( $\text{Si}$ on $\text{Cu}$ )(d,n) recoils in red P; Si
$^{37}_{18}\text{Ar}$	1610	4.6ns	[7/2]	-1.33 5		71Ra22	DPAD		$\text{K}^{37}\text{Cl}$ (pulsed p,n); $H_o = 16.6$ to $47\text{kG}$ calibrated using $^{19}\text{F}(197 \text{ level})$
$^{36}_{19}\text{K}$	gs	245ms	2	$\pm 0.547^p 2$		72Sc35	BAP— SE		$(^{87}\text{Rb} + ^{36}\text{Ar})(\text{p},\text{n})$
$^{37}_{19}\text{K}$	1380	10.5ns	[7/2]	+5.2 3		71Ra22	DPAD		( $\text{Ca}$ on $\text{Au}$ )(p, $\alpha$ ); $H_o = 8.2\text{kG}$ calibrated using $^{19}\text{F}(197 \text{ level})$
$^{41}_{19}\text{K}$	1290	7.3ns	[7/2]	+4.41 5		69Bl07	DPAD		( $^{41}\text{K}$ on $\text{Ta}$ )(p,p'); $H_o = 34\text{kG}$ ; used $g_{\text{ex}}(^{19}\text{F}-197) = 1.442 \ 3$

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat — Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{40}\text{Ca}$	3740	41ps	[3]	+0.45 <sup>p</sup> ± 24		70Be71 72He19	IMPAC	$\omega\tau=4.0$ 17 mr	(Ca on Fe)(p,p'); $H_o=1$ kG, $H_{bf}=-92$ 6kG; neglected transient fields
$^{40}\text{Ca}$	4490	272ps	[5]	+1.55 <sup>p</sup> ± 25		70Be71 72He19	IMPAC	$\pm H_{bf}$ at Ca in doubt (71Be69) $\omega\tau=54$ 9 mr	(Ca on Fe)(p,p'); $H_o=1$ kG, $H_{bf}=-92$ 6kG; neglected transients fields
$^{42}\text{Ca}$	3190	5.5ns	[6]	-2.52 18		70Ma39	IPAD	$\pm H_{bf}$ at Ca in doubt (71Be69)	(KI on Pt)( $\alpha$ ,p); $H_o=10.3$ kG
$^{42}\text{Ca}$	3190	5.5ns	[6]	-3.00 <sup>+12</sup> <sub>-18</sub>		71No06	DPAD	$\omega=-58.0$ 25Mr/s <sup>‡</sup> $=-74.8$ <sup>+30</sup> <sub>-40</sub> Mr/s <sup>‡</sup>	Ca metal(pulsed $\alpha$ ,2p); $H_o=24.20$ 15, 31.5 3kG; assumed $K$ negligible
								‡Unit given as MHz	
$^{41}\text{Sc}$	gs	0.59s	[7/2]	±5.43 <sup>d<sub>p</sub></sup> 2		72Su05	BAP— NMR		$^{40}\text{Ca}(\text{d},\text{n})$ recoils in Pt foil at 4.2°K; expect $K<0.26\%$
$^{43}\text{Sc}$	3123	450ns	[19/2]	+3.144 <sup>p</sup> 19		71Na10	DPAD Strob		Ca metal(pulsed $\alpha$ ,p); $H_o=$ 5.96 2, 3.64 1; ~7.5kG
$^{44}\text{Sc}$	69	153ns	[1]	+0.35 2		62Be19	DPAC	$\pm$ Assumed $K=(0.25$ 20)%	TiOF solution; $H_o=2648$ ; 5563G
$^{44}\text{Sc}$	69	153ns	[1]	+0.342 6		67Ri06	DPAC	$\omega=12.35$ Mr/s	$^{44}\text{Ti}$ in HCl; $H_o=7550$ G
$^{44}\text{Sc}$	69	153ns	[1]	±0.18 <sup>p</sup> ± 3		69Be77	PAC		BaTiO <sub>3</sub>
$^{47}\text{Sc}$	767	274ns	[3/2]	±0.35 5		68Fo02	DPAC	$\pm$ Antishielding correction made	( $^{44}\text{Ca}$ on Cu)( $\alpha$ ,p); $H_o=$ 6.10 6kG
$^{48}\text{V}$	$^{23}\text{V}$	gs	16d	(4)	±1.63 10	66Ca04	GAP	$\mu H=\pm 1.34$ 8nm-kG	Fe-V; $H_{int}=-82$ kG; $T$ measured by $^{54}\text{Mn}$ in Cu
$^{48}\text{V}$	306	7.09ns	[2]	+0.376 34		67Au02	IPAC	$G_2\omega\tau=0.331$ 13r, $G_2\omega\tau=0.407$ 23	liquid source, $H_o=36.4$ kG; $^{48}\text{Cr}$ in Cu metal, $H_o=46.6$ kG; $G_2=0.91$ 7; 0.95 6
$^{48}\text{V}$	306	7.09ns	[2]	±0.44 <sup>p</sup> 19 ±0.51 <sup>p</sup> 23		69Pa12	IPAC		dilute BaCrO <sub>4</sub> in HNO <sub>3</sub> ; $H_o=14.2$ kG
$^{51}\text{V}$	320	173ps	[5/2]	+4.2 7		63Kr02	NRF		(V metal powder)( $\gamma$ , $\gamma$ ) using gaseous $^{51}\text{CrCl}_2\text{O}_2$ $\gamma$ -source; $H_o=24.7$ kG; assumed $K=+0.6\%$ ( $H_{int}$ uncertain ~10%–65Ma27)
$^{51}\text{V}$	320	173ps	[5/2]	+3.85 32		68Ke09	IPAD	$\omega\tau=-0.163$ 14r, $\omega\tau=-0.161$ 21, $\omega\tau=-0.159$ 20	4.5%V-Fe alloy, 1%V-Fe alloy, 2%V-Fe alloy CEx with p; $H_{int}=87.3$ 18kG
$^{54}\text{Cr}$	$^{24}\text{Cr}$	749	7.5ns	[3/2]	±1.1 <sup>b†</sup> 7	69Ku18	DPAD		$^{50}\text{Cr}(\text{d},\text{p})$
$^{52}\text{Mn}$	$^{25}\text{Mn}$	gs	5.7d	(6)	positive <sup>‡</sup>	57Hu80	GAP		$\text{Ce}_2\text{Mg}_3(\text{NO}_3)_{12} \cdot 24$
$^{52}\text{Mn}$	$^{25}\text{Mn}$	gs	5.7d	6?	±2.98 15	61Je04	GAO	$\pm$ Measured circular polarization of $\gamma$	$\text{La}_2\text{Mg}_3(\text{NO}_3)_{12} \cdot 24$
$^{52}\text{Mn}$	$^{25}\text{Mn}$	gs	5.7d	(6)	+3.059 2	+0.53 11	70Ni11	$g^{52}/g^{55}=$ 0.36961 7	(Ce,La) <sub>2</sub> Mg <sub>3</sub> (NO <sub>3</sub> ) <sub>12</sub> ·24 at 0.1°K; used $\mu_{cor}^{55}=+3.449$ 2 or $Q^{52}/Q^{55}=+1.5$ 2
$^{54}\text{Mn}$	$^{25}\text{Mn}$	gs	312d	(3)	±2.5 2 positive <sup>‡</sup>		60Ba42	$g^{52}/g^{54}=0.60$	3.4680 3 and $Q^{55}=+0.35$ 5 (Zn,Ni)SiF <sub>6</sub> ·6; CMN; used $\mu^{52}=3.05$
$^{54}\text{Mn}$	$^{25}\text{Mn}$	gs	312d	3	±3.28 6	61Je04	GAO	$\pm$ Measured circular polarization of 840 $\gamma$	$\text{La}_2\text{Mg}_3(\text{NO}_3)_{12} \cdot 24$

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat — Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{54}_{25}\text{Mn}$	gs	312d	(3)	$\pm 3.284^d 5$ or $\pm 3.302^d 5$		67Te01	GAP— NMR	$\nu=189.9$ 3MHz	$^{54}\text{Mn}$ in Fe; $0.013^\circ\text{K}$ ; $H_o=675\text{G}$ ; $H_{hf}=-229.00\text{kG}$ ; recalculated using $\mu_{cor}^{55}=3.449$ 2 or 3.4680 3
$^{54}_{25}\text{Mn}$	gs	312d	(3)	+3.278 2 or +3.2959 4	+0.35 8	70Ni11	GAO— NMR	$g^{54}/g^{55}=+0.79199$ 6 $Q^{54}/Q^{55}=+0.99$ 10	$(\text{Ce},\text{La})_2\text{Mg}_3(\text{NO}_3)_{12} \cdot 24$ at $0.1^\circ\text{K}$ , used $\mu^{55}=+3.449$ 2 or 3.4680 3 and $Q^{55}=+0.35$ 5
$^{56}_{25}\text{Mn}$	gs	2.58h	(3)	$\pm 3.3$ 3 positive‡		60Ba06	GAP	$g^{52}/g^{56}=0.47$ 5	CMN; used $\mu^{52}=3.05$
$^{54}_{26}\text{Fe}$	1408	1.0ps	[2]	+2.86‡ 56		72Hu08 74Hu01	IMPAC	$\Delta\theta=-18.9$ 48mr, $\Delta\theta=-12.3$ 22mr	CEx with $^{16}\text{O}$ , recoils in Fe, $\text{Fe}_{0.8}-\text{Co}_{0.2}$ ; $H_m=-330$ , -364kG for Fe, alloy respectively
								‡Analyzed $\Delta\theta$ vs $E_{recoil}$ with transient field theory. Assumed 12% radiation damage correction to $H_{hf}$ .	
$^{54}_{26}\text{Fe}$	2950	1.22ns	[6]	$\pm 8.22$ 18		71He21	DPAD	$\omega=2230$ 50 Mr/s	$^{54}\text{Fe}(p,p')$ ; $H_o=2.5\text{kG}$ ; $H_{int}=-339\text{kG}$
$^{56}_{26}\text{Fe}$	847	6.9ps	[2]	+1.12 32		61Me11	NRF	$\omega\tau=\pm 0.485^\circ$	$\text{Fe}(\gamma,\gamma)$ using gaseous $^{56}\text{CoCl}_2$ $\gamma$ -source; $H_{int}=3.17\text{kG}$
$^{56}_{26}\text{Fe}$	847	6.9ps	[2]	+1.23‡ 34		63Ap01	IPAC	$\omega\tau=7.9$ ‡ 37mr	$^{56}\text{Co}$ diffused into Fe; $H_{int}=-330$ 10kG
								‡Corrected for other $\gamma$ 's coincident with 845 $\gamma$ and for influence of field on position of peaks	
$^{56}_{26}\text{Fe}$	847	6.93ps‡	[2]	+1.20‡ 20		72Hu08 74Hu01	IMPAC		Fe(p,p') recoils in Fe
								‡ $\Delta\theta$ vs $E_{recoil}$ fit with transient field theory	
$^{57}_{26}\text{Fe}$	136	8.8ns	[5/2]	$\pm 0.915$ 45		64Ko16	DPAD		( $^{57}\text{Fe}$ on Cu)(p,p'); $H_{int}=-333\text{kG}$
$^{57}_{26}\text{Fe}$	136	8.8ns	[5/2]	+0.85 12		69Sp05	IPAD	$\omega\tau=0.230$ 36r	Stainless steel
$^{57}_{26}\text{Fe}$	367	7ps	[3/2]	$ \mu <0.6$ or $H_{int} \neq 330\text{kG}$		69Sp05	IMPAC		( $^{57}\text{Fe}$ on Fe)(30MeV $O^{3+}, O'$ ); $H_o=11.0\text{kG}$
$^{57}_{26}\text{Fe}$	367	7ps	[3/2]	$ \mu <0.9$		74Hu01	IMPAC	$\Delta\theta=6$ 9mr	$^{57}\text{Fe}$ recoils in $\text{Fe}_{0.8}\text{Co}_{0.2}$ ; $H_{hf}$ (Static) = -364kG; $\Phi/g=-14.5\text{mr}$ expected from transient field theory including radiation damage
								correction to $H_{hf}$	
$^{57}_{26}\text{Fe}$	707	3ps	[5/2]	$ \mu <1.0$		74Hu01	IMPAC	$\Delta\theta=4.0$ 55mr	$^{57}\text{Fe}$ recoils in $\text{Fe}_{0.8}\text{Co}_{0.2}$ ; $H_{hf}$ (Static) = -364kG; $\Phi/g=-13.6\text{mr}$ expected from transient field theory including radiation damage corrections to $H_{hf}$
$^{58}_{26}\text{Fe}$	811	6.4ps	[2]	+1.08 34		69Si13	IPAC	$\omega\tau=7.73$ 175 mr	$^{58}\text{Co}$ in Fe; $H_o \approx 5\text{kG}$ , $H_m=323.4\text{kG}$ at room T
$^{59}_{26}\text{Fe}$	gs	45d	(3/2)	$\pm 1.1$ 2		70Ts04	GAO	$A^{59}/k=6.2$ 11m°K	$Nd_2\text{Zn}_3(\text{NO}_3)_{12} \cdot 24$ crystal; $Ce_2\text{Zn}_3(\text{NO}_3)_{12} \cdot 24$ crystal; used $A/k(^{57}\text{Fe})=1.57$ 4m°K
$^{55}_{27}\text{Co}$	gs	18h	[7/2]	$\pm 5.3$ or 4.5		60Ba20	GAP	$g^{58}/g^{55}=1.33$ or 1.55 10	$Ce_2\text{Mg}_3(\text{NO}_3)_{12} \cdot 24$ ; used $I^{58}=2$ , $\mu^{58}=4.03$
$^{55}_{27}\text{Co}$	gs	18h	[7/2]	$\pm 4.3$ 3		61Ch12	GAO		(Ni,Zn) $\text{SiF}_6$ 6 crystal; $^{60}\text{Co}$ used as thermometer

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat – Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{57}\text{Co}$	gs	270d	(7/2)	+4.722 <sup>d</sup> 17	+0.49 9	72Ni01	GAO–NMR	$A=+243.46$ 48MHz $B=+317.7$ 5MHz $P=+0.28$ 4MHz	(Ce,La) <sub>2</sub> (Mg,Co) <sub>3</sub> (NO <sub>3</sub> ) <sub>12</sub> •24; for $^{59}\text{Co}$ used $A=+79.096$ 4, $B=+103.91$ 4, $P=+0.0720$ 4 in units of ( $hcx10^{-4}\text{cm}^{-1}$ ) from ENDOR and $\mu_{\text{corr}}^{59}=4.616$ 9, $Q^{59}=+0.38$
$^{57}\text{Co}$	1378	19.4ps	[3/2]	+2.8 9		67Be17	IPAC		$\text{Fe}(\alpha, )$ ; $H_{\text{int}}=-290.6$ 9kG
$^{57}\text{Co}$	1378	19.4ps	[3/2]	+3.0 6		70Va10	IMPAC	$\omega\tau=70\text{mr}$	$^{54}\text{Fe}(\alpha, \text{n})$ ; $H_{\text{int}}=-290.6$ 9kG
$^{58}\text{Co}$	gs	71.3d	[2]	$\pm 3.5$ 3		52Da19	GAO		(Co,Cu,Zn)Rb <sub>2</sub> (SO <sub>4</sub> ) <sub>2</sub> •6
$^{58}\text{Co}$	gs	71.3d	[2]	+4.035 8	+0.21 3	72Ni01	GAP–NMR	$A=+362.73$ 4MHz $B=+476.75$ 20MHz $P=+0.41$ 2MHz	See $^{57}\text{Co}$ (72Ni01) above
$^{58}\text{Co}$	54	10.2 $\mu\text{s}$	[4]	+4.184 8		70Be33	Strob DPAD	$B_o=627.4$ 10 G for $T_o=1\mu\text{s}$	$^{57}\text{Fe}$ (pulsed d,n); target at $T=930^\circ\text{C}$ ( $T>T_c$ )
$^{59}\text{Co}$	1292	564ps	[3/2]	+1.99 35		67Ag03	IPAC		dilute FeCl <sub>3</sub> ; dilute FeCl <sub>2</sub> ;
$^{59}\text{Co}$	1292	564ps	[3/2]	+1.64 14		71Ar07	IPAC AAC	$g=+1.11$ 10 $g=\pm 1.04$ 16	$K_3\text{Fe}(\text{CN})_6$ ; $H_o=18.2\text{kG}$ , $\beta=1.5$
$^{60}\text{Co}$	gs	5.26y	(5)	$\pm 3.5$ 5		54Bl07	GAO	$\beta T=0.0112^\circ\text{K}$	$^{59}\text{Co}-\text{Fe}; H_o=13\text{kG}$ , $H_{\text{int}}=-276\text{kG}$ ; $^{59}\text{Co}-\text{Cu}$ , $^{59}\text{Co}-\text{Ni}$ , $^{59}\text{Co}-\text{Fe}$
$^{60}\text{Co}$	gs	5.26y	(5)	$\pm 4.3$ 2		55Po17	GAO		(Co,Cu,Zn)Rb <sub>2</sub> (SO <sub>4</sub> ) <sub>2</sub> •6;
$^{60}\text{Co}$	gs	5.26y	(5)	positive		55Wh42	GAP		used $\beta T^{59}=0.021^\circ\text{K}$ ; $\mu^{59}=4.62$
$^{60}\text{Co}$	gs	5.26y	(5)	+3.790 8	+0.42 5	72Ni01	GAP–NMR	$A=+136.22$ 7MHz $B=+179.08$ 8MHz $P=+0.113$ 5MHz	(Co,Cu,Zn)(NH <sub>4</sub> ) <sub>2</sub> (SO <sub>4</sub> ) <sub>2</sub> •6 crystal
$^{62}\text{Ni}$	87.2	1.72 $\mu\text{s}$	[5/2]	+0.752 2		70Bl06 71Bl15	DPAC		$^{62}\text{Ni}$ (pulsed d,p); $H_o=18.33\text{kG}$
$^{62}\text{Cu}$	41	4.80ns	[2]	$\pm 1.21$ 6		71Bl15	DPAC		$^{62}\text{Ni}$ (pulsed p,n); $H_o=28.0\text{kG}$
$^{62}\text{Cu}$	41	4.80ns	[2]	$\pm 1.34$ 12		71Bo64	IPAC DPAC	$\omega\tau=-0.56^{+56}_{-28}\text{r}$ $\omega=-44$ 8Mr/s	at $870^\circ, 970^\circ\text{K}$ ; $H_o=5.55, 11.1\text{kG}$ at $290^\circ\text{K}$ , $H_{\text{int}}=-41.8, -36.4\text{kG}$
$^{62}\text{Cu}$	390	11.5ns	[3]	$\pm 1.89^p$		69Su13	PAC		$\text{Ni}(\alpha, 2\text{n})$ ; aqueous ZnCl; $H_o=13.20$ 15kG
$^{64}\text{Cu}$	1590	20.4ns	[6]	+1.02 <sup>p</sup> 6		71Su09	PAC		aligned $^{60}\text{Ni}$ (pulsed $\alpha, \text{np}$ ),
$^{64}\text{Cu}$	1590	20.4ns	[6]	+1.06 <sup>p</sup> 3		72Bl14	DPAD		$H_{\text{hf}}=-47.2\text{kG}$
$^{66}\text{Cu}$	1154	596ns	[6]	+1.038 <sup>p</sup> 3		72Bl14	DPAD		aligned $^{62}\text{Ni}$ (pulsed $\alpha, \text{np}$ )
$^{67}\text{Zn}$	185	1.01ns	[3/2]	+0.38 12		68Li02	IPAC	$\omega\tau=3.1^\circ\ddagger$ †Corrected for strong annihilation background	Cu foils( $\alpha, 2\text{n}$ ); $H_o=31.2\text{kG}$
$^{67}\text{Zn}$	185	1.01ns	[3/2]	$\pm 0.51$ 6		69Bo41	IPAC		GaCl; $H_o=18.3\text{kG}$
$^{67}\text{Zn}$	185	1.01ns	[3/2]	+0.35 12		71Re01	DPAC		
$^{67}\text{Zn}$	605	340ns	[9/2]	-1.093 <sup>p</sup> 20		72Be61	IPAC DPAD		
$^{67}\text{Ge}$	734	70ns	[9/2]	-0.945 <sup>p</sup> 30		72Be61	DPAD		Zn(pulsed $\alpha, \text{n}$ );
$^{67}\text{Ge}$	734	70ns	[9/2]			72Ha69	DPAD	$Q/Q^{69}(398\text{keV})=$ 1.22 <sup>p</sup> 2	Ga(pulsed p, ); $T<T_{\text{melt}}$
$^{69}\text{Ge}$	398	2.8 $\mu\text{s}$	[9/2]	-1.0008 <sup>d</sup> 32		70Ch05	Strob	$B_o =$ $B_{\text{corr}}=$ 2.951 10kG for $T_o=1\mu\text{s}$	liquid $^{69}\text{Ga}$ (pulsed p,n); used $K_{\text{Ge}}=4.49$ 4x10 <sup>-3</sup> , $\sigma_{\text{Ge}}=2.8\times 10^{-3}$

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat – Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{70}_{32}\text{Ge}$	1040	1.3ps	[2]	+1.18 $\pm$ 58		69He11	IMPAC	$\Delta\theta=-11.2 \text{ } 15\text{mr}$	( $^{70}\text{Ge}$ on Fe)( $^{16}\text{O},\text{O}'$ ); $H_o \sim 1\text{kG}$ ; $H_{int}=+70 \text{ } 3\text{kG}$
$^{70}_{32}\text{Ge}$	1040	1.3ps	[2]	+1.76 $\pm$ 42		74Hu01 (69He11)	IMPAC	‡Includes estimate of transient field	$H_{hf}=+70 \text{ } 3\text{kG}$
$^{71}_{32}\text{Ge}$	175	79ns	[5/2]	+1.015 10		68Mo12	DPAD	‡Included effect of decays-in-flight	AuGa <sub>2</sub> (pulsed p,n), $H_o=15.98\text{kG}$ ; (Ga on Au)(pulsed p,n), $H_o=26.04\text{kG}$
$^{71}_{32}\text{Ge}$	175	79ns	[5/2]			72Ha69	DPAD	$Q/Q^{69}(398\text{keV})=0.219^{+4}$	Zn(pulsed $\alpha$ , ); Ga(pulsed p, ); $T < T_{melt}$
$^{71}_{32}\text{Ge}$	198	20.2ms	[9/2]	-1.022 23 -1.039 $\pm$ 23		70Be29	DPAD Strob	$B_o=355.8 \text{ } 8\text{G}$ for $T_o=64\mu\text{s}$	liquid $^{71}\text{Ga}$ (pulsed p,n); $H_o=98.7, 72.4\text{G}$ for DPAD
$^{71}_{32}\text{Ge}$	198	20.2ms	[9/2]		$\pm 0.28^{+10}$	72Ri13	‡	‡Measured relaxation time as f( $T$ ) by GAO	liquid Ga(pulsed p,n)
$^{72}_{32}\text{Ge}$	835	3.14ps	[2]	+1.00 50		69He11	IMPAC	$\Delta\theta=-9.9 \text{ } 17\text{mr}$	( $^{72}\text{Ge}$ on Fe)( $^{16}\text{O},\text{O}'$ ); $H_{int}=+70 \text{ } 3\text{kG}$
$^{72}_{32}\text{Ge}$	835	3.14ps	[2]	+1.16 $\pm$ 28		74Hu01 (69He11)	IMPAC	‡Included effect of decays-in-flight	$H_{hf}=+70 \text{ } 3\text{kG}$
$^{74}_{32}\text{Ge}$	596	12ps	[2]	+0.92 46		69He11	IMPAC	$\Delta\theta=-11.3 \text{ } 13\text{mr}$	( $^{74}\text{Ge}$ on Fe)( $^{16}\text{O},\text{O}'$ ); $H_{int}=+70 \text{ } 3\text{kG}$
$^{74}_{32}\text{Ge}$	596	12ps	[2]	+0.94 $\pm$ 20		74Hu01 (69He11)	IMPAC	‡Included effect of decays-in-flight	$H_{hf}=+70 \text{ } 3\text{kG}$
$^{76}_{32}\text{Ge}$	563	17.6ps	[2]	+0.74 36		69He11	IMPAC	$\Delta\theta=-9.9 \text{ } 15\text{mr}$	( $^{76}\text{Ge}$ on Fe)( $^{16}\text{O},\text{O}'$ ); $H_{int}=+70 \text{ } 3\text{kG}$
$^{76}_{32}\text{Ge}$	563	17.5ps	[2]	+0.72 $\pm$ 16		74Hu01 (69He11)	IMPAC	‡Included effect of decays-in-flight	$H_{hf}=+70 \text{ } 3\text{kG}$
$^{72}_{33}\text{As}$	215	80ns	[3]	+1.575 $\pm$ 18		72Be62	DPAD		$^{72}\text{Ge}$ (p,n)
$^{73}_{33}\text{As}$	66.9	5.0ns	[5/2]	+1.62 10		63Bo26	DPAC	$\nu=116 \text{ } 6\text{MHz}$	
$^{73}_{33}\text{As}$	427	5.8 $\mu\text{s}$	[9/2]	+5.157 $\pm$ 32		69Qu03	PAD–NMR	$ g (1+K)=1.1495 \text{ } 57$	liquid $^{71}\text{Ga}$ metal( $\alpha, 2\text{n}$ ); $H_1, \nu_1=8.5\text{G}, 858\text{kHz}; 12.4, 854; 17.0, 856; 14.6, 925$
$^{73}_{33}\text{As}$	427	5.8 $\mu\text{s}$	[9/2]	$\pm 5.234 \text{ } 13$		70Be23	Strob	‡Assumed $K=+0.32\%$	solid $^{72}\text{Ge}(\text{d},\text{n})$
$^{74}_{33}\text{As}$	274	26.8ns	[3]	+2.428 $\pm$ 30		71Ch10	DPAD	$\omega/\omega(^{19}\text{F}-197\text{keV})=+0.555 \text{ } 4$	$^{74}\text{Ge}$ metal(pulsed p,n); $H_o=21\text{kG}$ ; Knight shift negligible
$^{75}_{33}\text{As}$	265	11.9ps	[3/2]	$\pm 1.11 \text{ } 33$		71Be89	IPAC	$\omega\tau=9.0 \text{ } 24\text{mr}$	Se in Fe; $H_{eff}=150 \text{ } 17\text{kG}$
$^{75}_{33}\text{As}$	265	11.9ps	[3/2]	+0.93 $\pm$ 24		72Ch36	IPAC	$\omega\tau=16.2 \text{ } 4\text{mr}$	implantation in Fe foil by mass-separator; $H_{hf}=319 \text{ } 33\text{kG}$ measured using 280keV level
$^{75}_{33}\text{As}$	280	0.28ns	[5/2]	+0.90 28		60Ma03	IPAC	$G_2\omega\tau=-17.2 \text{ } 34\text{mr}$	$^{74}\text{Se}$ (pile n, ) dissolved in $\text{HNO}_3$ ; $H_o=13\text{kG}$ ; $\beta=1$ , $G_2 \sim 1$ material not given; $H_o=20\text{kG}$
$^{75}_{33}\text{As}$	280	0.28ns	[5/2]	+0.83 $\pm$ 18		66Ag01	IPAC	$\omega\tau=13.6 \text{ } 22\text{mr}$	$^{75}\text{Se}$ in $\text{HNO}_3$ ; $H_o=10\text{kG}$ ; used $\beta=1$ , $G_2=1$
$^{75}_{33}\text{As}$	280	0.28ns	[5/2]	$\pm 2.4 \text{ } 3$		70Az01	IPAC		$\text{H}_2\text{SeO}_3$ in dilute $\text{HCl}$ , $H_o=20\text{kG}$
$^{75}_{33}\text{As}$	280	0.28ns	[5/2]	$\pm 0.91 \text{ } 12$		71Be89	IPAC	$\omega\tau/H=0.698 \text{ } 75\text{r/MG}$ $\omega\tau=104.7 \text{ } 35\text{mr}$	Se in Fe, find $H_{eff}=150 \text{ } 17\text{kG}$ and $H_{hf}=145 \text{ } 18\text{kG}$
$^{76}_{33}\text{As}$	45	2.60 $\mu\text{s}$	[1]	+0.558 1		71Be90	Strob	$B_o=1175 \text{ } 2\text{G}$ for $T_o=1\mu\text{s}$	metallic $^{76}\text{Ge}$ (p,n)
$^{77}_{33}\text{As}$	473	116 $\mu\text{s}$	[9/2]	$\pm 5.508 \text{ } 9$		70Be78	Strob		liquid $^{76}\text{Ge}$ metal(d,n)

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat – Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{76}_{34}\text{Se}$	559	11.1ps	[2]	+0.80 24		67Mu10	IPAC	$\omega\tau=20$ 3mr	pure metal; Fe–As(pile n, ); $H_{\text{int}}=+650$ 150kG
$^{76}_{34}\text{Se}$	559	11.1ps	[2]	+0.80 22		69He11	IMPAC	$\Delta\theta=-27.1$ 15mr	( $^{76}\text{Se}$ on Fe)( $^{16}\text{O},\text{O}'$ ); $H_o \approx 1\text{kG}$
$^{77}_{34}\text{Se}$	249	9.4ns	[5/2]	+1.20 15		64En01	DPAC	$\omega=75$ 8Mr/s	$H_{\text{int}}=+650$ 150kG
$^{77}_{34}\text{Se}$	440	24ps	[5/2]	+1.02 28		70Ro32	IMPAC	$\Delta\theta=-53.0$ 88mr	K $^{77}\text{Br}$ ; $H_o=33\text{kG}$
$^{78}_{34}\text{Se}$	614	8.6ps	[2]	+0.82 22		69He11	IMPAC	$\Delta\theta=-24.0$ 16mr	recoils in Fe; $H_{\text{int}}=+650$ 150kG;
$^{80}_{34}\text{Se}$	666	8.05ps	[2]	+0.84 24		69He11	IMPAC	$\Delta\theta=-23.9$ 11mr	$H_{\text{int}}=+650$ 150kG
$^{82}_{34}\text{Se}$	655	11.3ps	[2]	+0.86 24		69He11	IMPAC	$\Delta\theta=-29.5$ 8mr	( $^{82}\text{Se}$ on Fe)( $^{16}\text{O},\text{O}'$ ); $H_{\text{int}}=+650$ 150kG
$^{78}_{35}\text{Br}$	181	100μs	[4]	$\pm 4.100 \pm 12$		71Br31	PAD–NMR		molten Se–Tl(pulsed p,n); $H_o=6.5\text{G}$
$^{78}_{35}\text{Br}$	181	100μs	[4]	+4.08± 8		71In04	DPAD	‡Uncorrected for Knight shift or diamagnetism	Molten Se–Tl(390°C) (pulsed p, ); $H_o=51.5$ 5, 63.8 1, 96.3 9G $\tau_{\text{relax}}=40$ 30μs
$^{81}_{35}\text{Br}$	540	35μs	[9/2]	$\pm 5.84 \pm 7$		71Br31	PAD–NMR	‡Uncorrected for Knight shift or diamagnetism	molten Se–Tl (pulsed d,n); $H_o=10.4\text{G}$
$^{81}_{35}\text{Br}$	540	35μs	[9/2]	$\pm 5.674 \pm 45$		71Ch28	Strob	‡Uncorrected for Knight shift or diamagnetism $\omega_o=391.70\text{kr/s}$ for $n=2$ ; $H_o=64.87\text{G}$	Se–Tl at 450°C(pulsed 10MeV d, ); $\tau_{\text{relax}}=24$ 11μs
$^{82}_{35}\text{Br}$	gs	36h	(5)	positive		71Hi12	BAP	‡Uncorrected for Knight shift or diamagnetism	$^{82}\text{Br}$ and $^{57}\text{Co}$ implanted in Fe; $T \sim 30\text{m}^\circ\text{K}$
$^{79}_{36}\text{Kr}$	148	77.7ns	[5/2]	+1.122 10		68Bl04	DPAD		aqueous( $\text{K}^{19}\text{F}+\text{K}^{79}\text{Br}$ )(pulsed p,n); $H_o \sim 25\text{kG}$ ; used $g(\text{F}_{\text{ex}})=1.445$ 3
$^{83}_{36}\text{Kr}$	9.3	143ns	[7/2]	$-1.82 \pm 25$		67Mi17	DPAC	$2\omega_{\text{spin}}=29.6 \pm 1\text{Mr/s} \pm$	RbCl at 23°C; $H_o=1.7\text{kG}$ ; polycrystalline $\text{Rb}_2\text{Mg}(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$
					≈ 1 <sup>p</sup>			‡Unit given as MHz	
								†Values as reported in paper	
$^{86}_{38}\text{Sr}$	?	460ns	[8]	$-1.93 \pm 12$		72Ha66	DPAD	$\omega=8.46$ 50Mr/s	$^{88}\text{Sr}(\text{p},\text{n})$ ; $H_o=7.27\text{kG}$
$^{86}_{39}\text{Y}$	243	28.5ns	[2]	-1.06 6		68Tr11	DPAC		As( $^{16}\text{O},5\text{n}$ )Zr, chem; Zr in 1M HF solution; $H_o \sim 41\text{kG}$ ; $\beta=1$ assumed
$^{90}_{40}\text{Zr}$	3590	130ns	[8]	$\pm 10.84$ 14		70Na13 71Na16	Strob	$\omega=78.55$ 79Mr/s‡	Sr metal( $\alpha,2\text{n}$ ); $H_o=12.00$ 4kG; $K=0.87\%$ assumed
$^{91}_{40}\text{Zr}$	>2265	29.0ns	[15/2]	$\pm 5.32 \pm 8$		72Ba82	DPAD	‡Unit given as MHz	$^{88}\text{Sr}(\alpha,\text{n})$

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat – Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{91}_{41}\text{Nb}$ $^{95}_{41}\text{Nb}$	2378 gs	10.0ns 35d	[17/2] [9/2]	$\pm 10.62^p 34$ $\pm 6.3 6$ $\mu H < 0$		72Ba82 67Ca07	DPAD GAP		$^{89}\text{Y}(\alpha, 2n)$ dilute Nb–Fe; Nb–Co alloys; $H_{\text{int}}(\text{in Fe})=255\text{kG}$ from NMR measured circular polarization of $768\gamma$
$^{92}_{42}\text{Mo}$	2761	190ns	[8]	$\pm 11.2 6$		70Co28 71Co08	DPAC	$\omega=25.5 12\text{Mr/s}$	$^{90}\text{Zr}$ foil( $\alpha, 2n$ ); $H_o=3.8 1\text{kG}$
$^{92}_{42}\text{Mo}$	2761	190ns	[8]	$\pm 11.27 13$		70Na13 71Na16	Strob	$\omega(1)=$ $70.37 63\text{Mr/s} \ddagger$ $\omega(2)=$ $71.05 64\text{Mr/s} \ddagger$ $\ddagger$ Unit given as MHz	$^{90}\text{Zr}$ metal on Zr( $\alpha, 2n$ ); $H_o=$ $10.39 2\text{kG}$ ; (1)= $773\gamma$ , (2)= $1511\gamma$
$^{94}_{42}\text{Mo}$ $^{95}_{42}\text{Mo}$	2953 204	97.7ns 760ps	[8] [3/2]	$\pm 10.54^p 16$ $-0.55 6$		72Fa16 66An02	DPAD IPAC		$^{92}\text{Zr}(\alpha, 2n)$ ; $H_o=15.85\text{kG}$ solid Mo(d, )
$^{95}_{42}\text{Mo}$	204	760ps	[3/2]	$-0.39 3$		70Bo28	IPAC	$\omega\tau=-44 3\text{mr}$ $\omega\tau=-37.5 80\text{mr}$	liquid HTcO <sub>4</sub> +H <sub>2</sub> MoO <sub>4</sub> in HNO <sub>3</sub> ; $H_o=22.5 3\text{kG}$
$^{98}_{42}\text{Mo}$	787	3.5ps	[2]	$+0.68 36$		69Hell	IMPAC	$\omega\tau=+28.0 17\text{mr}$ (average for 2 cascades)	Nb foil( $\alpha, 2n$ ); $H_o=20.6 4\text{kG}$ assumed
$^{100}_{42}\text{Mo}$	536	10ps	[2]	$+0.68 36$		69Hell	IMPAC	$\Delta\theta=-12.1 30\text{mr}$	$^{98}\text{Mo}$ on Fe(O,O'); $H_o \sim 1\text{kG}$ ; $H_{\text{int}}=-256 5\text{kG}$
$^{96}_{43}\text{Tc}$	gs	4.3d	[6]	$\pm 4.60 14$		71Fo24	GAP– NMR	$\nu=173.23 5\text{MHz}$ , $171.45 5$ , $168.88 8$	Tc–Fe; $H_o=1.317, 4.39, 8.78\text{kG}$ ; Obtain $g$ from slope of $\nu$ vs $H_o$ and $H_{\text{int}}=-298 10\text{kG}$ from intercept
$^{99}_{43}\text{Tc}$ $^{99}_{43}\text{Tc}$	141 141	192ps 192ps	[7/2] [7/2]	$\pm 3.8 12$ $+4.7 12$		68Za04 69In07	IPAC IPAC	$\omega\tau=30 10\text{mr}$ $\omega\tau=+0.58 10\text{r}$	solid MoO <sub>3</sub> ; $H_o=20 1\text{kG}$ Mo–Fe(pile n, ); assumed $H_{\text{int}}=-320 65\text{kG}$
$^{99}_{43}\text{Tc}$	181	3.59ns	[5/2]	$\pm 3.6 5$ positive		58Ra16	AAC IPAC		Mo wire dissolved in HNO <sub>3</sub> ; $H_o=10\text{kG}$
$^{99}_{43}\text{Tc}$	181	3.59ns	[5/2]	$+3.6 4$		59Bo43	IPAC	$G_2=0.81 5$	fission Mo in (NH <sub>4</sub> ) <sub>2</sub> MoO <sub>4</sub> ; $H_o=15.55\text{kG}$ ( $H_{\text{int}}$ uncertain $\sim 10\%, 65\text{Ma27}$ )
$^{99}_{43}\text{Tc}$ $^{99}_{43}\text{Tc}$	181 181	3.59ns 3.59ns	[5/2] [5/2]	$+3.6 3$ $+3.28 6$		65An02 71Wi08	IPAC DPAC		(NH <sub>4</sub> ) <sub>2</sub> MoO <sub>4</sub> ; $H_o=16.00 25\text{kG}$ Tc–Cu; $H_o=29.80 15\text{kG}$
$^{98}_{44}\text{Ru}$	654	5.9ps	[2]	$+0.60 34$		69Hell	IMPAC	$\omega\tau=-5.0 40\text{mr}$	$^{98}\text{Ru}$ on Fe( <sup>16</sup> O,O'); $H_{\text{int}}=-505 15\text{kG}$
$^{98}_{44}\text{Ru}$	654	5.9ps	[2]	$+0.78^e \ddagger 60$		74Hu01 (69Hell)	IMPAC	$\ddagger$ Used $H_{\text{bf}}$ (IMPAC) = $-359 44\text{kG}$ , based on $g_{\text{ave}}(2+) = 0.40 3$ , and $\Phi_i = -10.7 24\text{mr}$ ; included effect of decays-in-flight	
$^{99}_{44}\text{Ru}$	gs	—	(5/2)	$-0.623 \ddagger 21$		65Ma27	DPAC	$\ddagger$ Using $\mu(90)/\mu(\text{gs}) = +0.455 16$ from Mössbauer experiments (66Ki02) and $g(90) = -0.189 4$ ; Ru in Cu	
$^{99}_{44}\text{Ru}$	90	20.7ns	(3/2)	$-0.392 40$		64Bo28	DPAC	$\omega=$ $38.7 11 \times 10^6 \text{s}^{-1} \ddagger$ $\ddagger$ Unit as given	liquid RhCl <sub>3</sub> in 3N HCl; ( $H_{\text{int}}$ uncertain $\sim 10\%, 65\text{Ma27}$ )
$^{99}_{44}\text{Ru}$	90	20.7ns	(3/2)	$-0.284 6$		65Ma27	DPAC	$g=-0.181 2$ $g=-0.189 2$ $g=\pm 0.184 10$	liquid source; $H_o=41.6 4\text{kG}$ Ru in Cu; $H_o=41.5 4\text{kG}$ , $\beta \approx 0.958$ Ru in Ni; $H_{\text{int}}=-180 10\text{kG}$
				negative			IPAC		

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat — Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{100}_{44}\text{Ru}$	540	11.9ps	[2]	+1.02 13		66Au06	IPAC	$\omega\tau=-17.8$ 12mr	$^{100}\text{Ru}$ in Fe; $H_o=10\text{kG}$ , $H_{int}=-442$ 31kG
$^{100}_{44}\text{Ru}$	540	11.9ps	[2]			69He11	IMPAC	$\Delta\theta=3.3$ 32mr	( $^{100}\text{Ru}$ on Fe)( $^{16}\text{O}, \text{O}'$ ); $H_o=1\text{kG}$ ; $H_{int}=-505$ 15kG
$^{100}_{44}\text{Ru}$	540	11.9ps	[2]	+0.94 <sup>c</sup> ‡ 30		74Hu01 (69He11)	IMPAC	‡See $^{98}\text{Ru}(654)$ , 74Hu01	
$^{101}_{44}\text{Ru}$	127	550ps	[3/2]	-0.310 26		66Au06	IPAC	$\omega\tau=+336$ 13mr	$^{101}\text{Ru}$ in Fe; $H_o=10\text{kG}$ , $H_{int}=-442$ 31kG
$^{102}_{44}\text{Ru}$	475	17.6ps	[2]	+0.80 18		66Au06	IPAC	$\omega\tau=+130$ 4mr	$^{101}\text{Ru}$ in Ni; $H_{int}=-178$ 8kG
$^{102}_{44}\text{Ru}$	475	17.6ps	[2]	$\pm 0.76^{ap}$ 50		68Fr17	PAC	$\omega\tau=-20.9$ 42mr	$^{102}\text{Ru}$ in Fe; $H_o=10\text{kG}$ , $H_{int}=-442$ 31kG
$^{102}_{44}\text{Ru}$	475	17.6ps	[2]			69He11	IMPAC	$\Delta\theta=2.8$ 44mr	Ru diffused in Fe; $H_{int}=500$ 2kG
$^{102}_{44}\text{Ru}$	475	17.6ps	[2]	+0.741 62		72Jo06	IPAC	$\omega\tau=-21.7$ 12mr	Rh in Fe at liquid He temp; $H_o=22\text{kG}$ ; $H_{hf}=-503$ 9kG
$^{102}_{44}\text{Ru}$	475	17.6ps	[2]	+0.62 <sup>c</sup> ‡ 24		74Hu01 (69He11)	IMPAC	‡See $^{98}\text{Ru}(654)$ , 74Hu01	
$^{104}_{44}\text{Ru}$	358	58ps	[2]	+0.58 8		69He11	IMPAC	$\Delta\theta=47.8$ 44mr	( $^{104}\text{Ru}$ on Fe)( $^{16}\text{O}, \text{O}'$ ); $H_{int}=-505$ 15kG
$^{104}_{44}\text{Ru}$	358	58ps	[2]	+0.82 <sup>c</sup> ‡ 10		74Hu01 (69He11)	IMPAC	‡Used $H_{hf}$ (IMPAC) = -359 44kG, based on $g_{ave}(2+)=0.40$ 3, and $\Phi_i=-10.7$ 24mr; included effect of decays-in-flight	
$^{100}_{45}\text{Rh}$	74.8	215ns	[2]	+4.26 6		65Ma34	DPAC		metallic Rh; $H_o=2.22\text{kG}$ ; assumed $K=+0.43\%$
$^{100}_{45}\text{Rh}$	74.8	215ns	[2]	+4.321 <sup>d</sup> 8		66Ma54	DPAC	$2\nu=16.49$ 5, 25.10 5MHz	metallic Rh; $H_o=4996$ 10G, 7636 7G; assumed $K=+0.43\%$
$^{100}_{45}\text{Rh}$	74.8	215ns	[2]	$\pm 4.298^d$ 30		71Re06	DPAD		$^{103}\text{Rh}$ metal(p,4n); $G'=0.79$ 1; $H_o$ measured by proton resonance with Hall probe; assumed $K=0.43\%$
$^{103}_{45}\text{Rh}$	93	1.13ns	[9/2]	$\pm 6.21$ 90		71BaA1	IPAC		dilute $\text{RuCl}_4$ ; $H_o=18.5\text{kG}$ , $\beta=1$ ; Ru source in Cu
$^{103}_{45}\text{Rh}$	298	6.3ps‡	[3/2]	+0.03 39		70Ro32	IMPAC	$\Delta\theta=+3.6$ 50mr	recoils in Fe; $H_{int}=-543$ 11kG, $H\tau_i=7.4$ 15MG-ps assumed
$^{103}_{45}\text{Rh}$	298	6.3ps‡	[3/2]	$\pm 1.72$ 46 or $\pm 2.12$ 63		71Bh05	IMPAC	‡Value of $T_{1/2}$ used in analysis $\Delta\theta=+29$ 7mr	5%Rh-Fe alloy; $H_{int}=-540\text{kG}$ ; assumed no transient fields or assumed $H\tau_i=1.24\text{MG-ps}$
$^{103}_{45}\text{Rh}$	298	7.6ps‡	[3/2]	$\pm 0.90^{ap}$ 30		71Sp14	AAC	‡Value of $T_{1/2}$ used in analysis $g(3/2)/g(5/2)=1.3$ 3	Rh( $^{35}\text{Cl}, \text{Cl}'$ ) recoils in gas
$^{103}_{45}\text{Rh}$	298	6.3ps	[3/2]	$\pm 0.70^{ap}$ 21		72Mi20	PAC	‡Value of $T_{1/2}$ used in analysis	recoils in gas
$^{103}_{45}\text{Rh}$	360	59ps	[5/2]	+1.38 25‡		70Ro32	IMPAC	$\Delta\theta=+102.7$ 70mr	recoils in Fe; $H_{int}=-543$ 11kG $H\tau_i=7.4$ 15MG-ps assumed
$^{103}_{45}\text{Rh}$	360	59ps	[5/2]	$\pm 1.2$ 2		71Bh05	IMPAC	‡Uncertainty increased to ~ 20%	5%Rh-Fe alloy; $H_{int}=-540\text{kG}$ , assumed no transient field or $H\tau_i=1.24\text{MG-ps}$
$^{103}_{45}\text{Rh}$	360	76ps‡	[5/2]	$\pm 1.12^{ap}$ 25		71Sp14	AAC	‡Value of $T_{1/2}$ used in analysis	Rh( $^{35}\text{Cl}, \text{Cl}'$ ) recoils in gas
$^{103}_{45}\text{Rh}$	360	59ps	[5/2]	$\pm 0.95^{ap}$ 32		72Mi20	PAC		recoils in gas

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat – Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{104}_{46}\text{Pd}$	556	9.7ps	[2]			69He11	IMPAC	$\Delta\theta=-0.8 \text{ } 14\text{mr}$	( $^{104}\text{Pd}$ on Fe)( $^{16}\text{O}, \text{O}'$ ); $H_o \approx 1\text{kG}$ $H_{int} = -595 \text{ } 12\text{kG}$
$^{104}_{46}\text{Pd}$	556	9.7ps	[2]	+0.76 $\pm$ 14		74Hu01	IMPAC	$\Delta\theta=1.3 \text{ } 12\text{mr}$	CEx with $^{16}\text{O}$ , recoils in disordered $\text{Fe}_{0.8}\text{Co}_{0.2}$ ; $H_{hf}(\text{IMPAC})=-409 \text{ } 31\text{kG}$ , $\Phi_i = -9.3 \text{ } 14\text{mr}$
				+0.62 $\pm$ 16	(69He11)			‡Calculated assuming $g_{ave}(2+)=0.36$ , $H_{hf}(\text{IMPAC})=-409\text{kG}$	
$^{106}_{46}\text{Pd}$	512	12.7ps	[2]	+0.85 11		65Ko12	IPAC	$\omega\tau=2.06 \text{ } 20\text{mr}$	$\text{RuCl}_3$ in 3N HCl; $H_o = 55.62\text{kG}$
$^{106}_{46}\text{Pd}$	512	12.7ps	[2]	+0.75 8		66Je02	IPAC	$\omega\tau=-17.6 \text{ } 3\text{mr}$	$^{106}\text{Pd}$ in Fe; $H_{int} = -540 \text{ } 40\text{kG}$
					66Au06	IPAC	$\omega\tau=-11.6 \text{ } 7\text{mr}$	$^{106}\text{Pd}$ in Co; $H_{int} = -361 \text{ } 50\text{kG}$	
								$\omega\tau=-50 \text{ } 9\text{mr}$	$^{106}\text{Pd}$ in Ni; $H_{int} = -162 \text{ } 35\text{kG}$
$^{106}_{46}\text{Pd}$	512	12.7ps	[2]	$\pm 0.70 \text{ } 6$		67Mu09	IPAC		Ru in Fe; $H_{int} = 580 \text{ } 20\text{kG}$
$^{106}_{46}\text{Pd}$	512	12.7ps	[2]	$\pm 0.690 \text{ } 53$		68Bo15	IPAC	$\omega\tau=17.3 \text{ } 2\text{mr}$	Ru in Co; $H_{int} = 397 \text{ } 15\text{kG}$
$^{106}_{46}\text{Pd}$	512	12.7ps	[2]	$\pm 0.75 \text{ } 7$		68Jo17	IPAC	$\omega\tau=1.73 \text{ } 11\text{mr}$	$^{106}\text{Ru}$ in Fe; $H_{int} = -573 \text{ } 20\text{kG}$
				$\pm 0.70 \text{ } 9$				$\omega\tau=1.42 \text{ } 16\text{mr}$	Ru in Cu or stainless steel; $H_o = 51.1\text{kG}$
$^{106}_{46}\text{Pd}$	512	12.7ps	[2]	+0.58 34		69He11	IMPAC	$\Delta\theta=4.5 \text{ } 26\text{mr}$	$\text{RuCl}_3$ in 3N HCl; $H_o = 51.1\text{kG}$ , assumed $\beta=1$
$^{106}_{46}\text{Pd}$	512	12.7ps	[2]	$\pm 0.73 \text{ } 6$		70Si20	IPAC	$\omega\tau=18.1 \text{ } 8\text{mr}$	( $^{106}\text{Pd}$ on Fe)( $^{16}\text{O}, \text{O}'$ ); $H_{int} = -595 \text{ } 12\text{kG}$
$^{106}_{46}\text{Pd}$	512	12.7ps	[2]	+0.754 54		72Jo06	IPAC	$\omega\tau/B=33.7 \text{ } 10\text{mr/MG}$	$^{106}\text{Ru}-\text{Fe}; H_o = 6.5\text{kG}$ ; $H_{int} = 571\text{kG}$
								$(\omega\tau/B)_{ave} = 31.74 \text{ } 56\text{mr/MG}$	Pd-Co at $T < 0.25T_C$ ; $H_o > 20\text{kG}$ ; also measured in Pd-Fe, -Ni, –steel
$^{106}_{46}\text{Pd}$	512	12.7ps	[2]	+0.64 12, +0.74 $\pm$ 14		74Hu01	IMPAC	$\Delta\theta=20 \text{ } 15\text{mr}$ , $\Delta\theta=3.5 \text{ } 14\text{mr}$	CEx with $^{16}\text{O}$ , recoils in disordered $\text{Fe}_{0.8}\text{Co}_{0.2}$ , in Fe; $H_{hf}(\text{IMPAC})=-409 \text{ } 36\text{kG}$ and $\Phi_i = -9.3 \text{ } 14\text{mr}$ for both.
								‡Average value (this work and that of 69He11, recalculated) for recoils in Fe	
$^{106}_{46}\text{Pd}$	1128	2.5ps	[2]	+0.71 13		68Bo15	IPAC	$\omega\tau=3.63 \text{ } 47\text{mr}$	$^{106}\text{Ru}$ in Fe; $H_{int} = -573 \text{ } 20\text{kG}$ at room $T$
$^{106}_{46}\text{Pd}$	1128	2.5ps	[2]	$\pm 0.77 \text{ } 23$		70Si20	IPAC	$\omega\tau=3.8 \text{ } 10\text{mr}$	$^{106}\text{Ru}-\text{Fe}; H_o = 6.5\text{kG}$ ; $H_{int} = 571\text{kG}$
$^{108}_{46}\text{Pd}$	434	23.8ps	[2]	+0.60 8		69He11	IMPAC	$\Delta\theta=17.5 \text{ } 16\text{mr}$	( $^{108}\text{Pd}$ on Fe)( $^{16}\text{O}, \text{O}'$ ); $H_{int} = -595 \text{ } 12\text{kG}$
$^{108}_{46}\text{Pd}$	434	23.8ps	[2]	+0.74 8 +0.80 $\pm$ 12		74Hu01 (69He11)	IMPAC	$\Delta\theta=15.6 \text{ } 12\text{mr}$	CEx with $^{16}\text{O}$ , recoils in disordered $\text{Fe}_{0.8}\text{Co}_{0.2}$ ; $H_{hf}(\text{IMPAC})=-409 \text{ } 31\text{kG}$ $\Phi_i = -9.3 \text{ } 14\text{mr}$
$^{110}_{46}\text{Pd}$	374	45.8ps	[2]	+0.50 6		69He11	IMPAC	‡ $H_{hf} + \Phi_i$ for Fe same as for alloy	( $^{110}\text{Pd}$ on Fe)( $^{16}\text{O}, \text{O}'$ ); $H_{int} = -595 \text{ } 12\text{kG}$
$^{110}_{46}\text{Pd}$	374	45.8ps	[2]	+0.72 8		74Hu01	IMPAC	$\Delta\theta=35.0 \text{ } 23\text{mr}$	CEx with $^{16}\text{O}$ , recoils in disordered $\text{Fe}_{0.8}\text{Co}_{0.2}$ ; $H_{hf}$ (IMPAC)=-409 $31\text{kG}$ ; $\Phi_i = -9.3 \text{ } 14\text{mr}$
				+0.68 $\pm$ 8	(69He11)			‡ $H_{hf}$ and $\Phi_i$ for Fe same as for alloy	
$^{107}_{47}\text{Ag}$	325	5.9ps	[3/2]	+1.17 72		70Ro32	IMPAC	$\Delta\theta=-10.4 \text{ } 20\text{mr}$	recoils in Fe; $H_{int} = -282 \text{ } 20\text{kG}$ $H_{\tau_i} = 7.4 \text{ } 15\text{MG-ps}$ assumed
$^{107}_{47}\text{Ag}$	325	5.9ps	[3/2]	$\pm 0.75 \text{ } 22$		71Sp14	AAC	$g(3/2)/g(5/2) = \pm 1.25 \text{ } 30$	CEx recoils in He gas $H_{\tau_i} = 7.4 \text{ } 15\text{MG-ps}$ assumed

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat – Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{107}_{47}\text{Ag}$	325	5.9ps	[3/2]	$\pm 0.61^{\text{sp}} 21$		72Mi20	PAC		recoils in gas
$^{107}_{47}\text{Ag}$	423	34ps	[5/2]	$+1.65 70$		70Ro32	IMPAC	$\Delta\theta=+22.7 20\text{mr}$	recoils in Fe; $H_{\text{int}}=-282 20\text{kG}$
$^{107}_{47}\text{Ag}$	423	34ps	[5/2]	$\pm 0.88^{\text{sp}} 22$		71Sp14	AAC		CEx recoils in He gas
$^{107}_{47}\text{Ag}$	423	34ps	[5/2]	$\pm 0.87^{\text{sp}} 32$		72Mi20	PAC		recoils in gas
$^{109}_{47}\text{Ag}$	309	5.2ps	[3/2]	$+1.72 70$		70Ro32	IMPAC	$\Delta\theta=-8.9 24\text{mr}$	recoils in Fe; $H_{\text{int}}=-282 20\text{kG}$
$^{109}_{47}\text{Ag}$	309	5.2ps	[3/2]	$\pm 1.29^{\text{sp}} 30$		71Sp14	AAC	$g(3/2)/g(5/2)=\pm 1.4 4$	$H_{\text{int}}=7.4 15\text{MG-ps}$ assumed CEx recoils in He gas
$^{109}_{47}\text{Ag}$	309	5.2ps	[3/2]	$\pm 0.67^{\text{sp}} 22$		72Mi20	PAC		recoils in gas
$^{109}_{47}\text{Ag}$	414	33ps	[5/2]	$+1.21 56$		70Ro32	IMPAC	$\Delta\theta=+16.5 25\text{mr}$	recoils in Fe; $H_{\text{int}}=-282 20\text{kG}$
$^{109}_{47}\text{Ag}$	414	33ps	[5/2]	$\pm 1.06^{\text{sp}} 27$		71Sp14	AAC		CEx recoils in He gas
$^{109}_{47}\text{Ag}$	414	33ps	[5/2]	$\pm 0.67^{\text{sp}} 22$		72Mi20	PAC		recoils in gas
$^{110}_{47}\text{Ag}$	gs	24.4s	(1)	$\pm 2.72 10^d 8$		69Ac02	BAP–NMR	$\gamma/2\pi=2.0645 4\text{kHz/G}$	$\text{AgF}, \text{AgCl}, \text{AgBr}, \text{Ag}_2\text{O}$ , and $\text{Ag}_2\text{O}_2$ (polarized n, ); $T\sim 8^\circ\text{K}$ ; $2H_1=0.6\text{G}$
$^{110}_{47}\text{Ag}$	116	253d	(6)	$+2.9 13$		65We02	GAP	$\mu H=\pm 1.00 7 \text{ nm-MG}$ $\mu H=\pm 0.31 4\text{nm-MG}$ $\mu H$ negative from $\beta$ asymmetry	Ag in Fe; $H_{\text{int}}=-350 100\text{kG}$ Ag in Ni; $H_{\text{int}}=-108 30\text{kG}$ ; used GAO in $^{60}\text{Co}$ to measure temperature
$^{109}_{48}\text{Cd}$	469	8.9 $\mu\text{s}$	[11/2]	$-1.091^{\text{sp}} 2$		71Bl16	Strob		$^{109}\text{Ag}$ (pulsed p,n); $T=1000 10^\circ\text{C}$
$^{110}_{48}\text{Cd}$	656	5.0ps	[2]	$\pm 0.54^{\text{sp}} 22$		68Ke17	IPAC		Cd in Fe; $H_{\text{int}}=-348\text{kG}$ ; $\text{AgNO}_3$ melted into Fe;
$^{110}_{48}\text{Cd}$	656	5.0ps	[2]	$+0.78 30$		69He11	IMPAC	$\Delta\theta=-10.7 38\text{mr}$	$\text{AgNO}_3$ diffused into Fe ( $^{110}\text{Cd}$ on Fe)( $^{16}\text{O}, \text{O}'$ ); $H_{\text{int}}=-348 10\text{kG}$
$^{110}_{48}\text{Cd}$	656	5.0ps	[2]	$+0.64 13$		72Jo06	IPAC	$\omega\tau=3.2 6\text{mr}$	Ag–Gd at $77^\circ\text{K}$ ; $H_o=22\text{kG}$ , $H_{\text{hf}}=-310 7\text{kG}$
$^{110}_{48}\text{Cd}$	656	5.0ps	[2]	$+1.00^c \pm 44$		74Hu01 (69He11)	IMPAC	#Assumed $g_{\text{ave}}(2+)=0.36$ ; $H_{\text{hf}}$ (IMPAC)= $-238 131\text{kG}$ ; included effect of decays-in-flight	
$^{111}_{48}\text{Cd}$	247	84ns	[5/2]	$-0.70^*$		52Ae01	PAC		
$^{111}_{48}\text{Cd}$	247	84ns	[5/2]	$-0.72 5$		54Al49	AAC		$\text{InCl}_3$ in $\text{H}_2\text{O}$
$^{111}_{48}\text{Cd}$	247	84ns	[5/2]	$-0.783 23$		56St63	CDPAC		dilute $\text{InCl}_3$ solution
$^{111}_{48}\text{Cd}$	247	84ns	[5/2]		+0.9	62Be12	PAC	$\omega_0\tau=-1.5 5$	In crystal; measured circular polarization of $247\gamma$
								#Unit not given	
$^{111}_{48}\text{Cd}$	247	84ns	[5/2]	$-0.794^d 6$		63Bo09	DPAC		Cd in $\text{HCl}$ ; $H_o=10337 50\text{G}$
$^{111}_{48}\text{Cd}$	247	84ns	[5/2]	$-0.794^d 18$		63Ma10	DPAC		In in $\text{HNO}_3$ , $H_o=32.6\text{kG}$
				$-0.781^d 38$		63Sa19	DPAC	$\omega=47.35 \text{ Mr/s}$	In in $\text{HNO}_3$ , $H_o=31.81\text{kG}$
$^{112}_{48}\text{Cd}$	617	6.2ps	[2]	$+0.60 12$		69He11	IMPAC	$\Delta\theta=-7.3 9\text{mr}$	( $^{112}\text{Cd}$ on Fe)( $^{16}\text{O}, \text{O}'$ ); $H_{\text{int}}=-348 10\text{kG}$
$^{112}_{48}\text{Cd}$	617	6.2ps	[2]	$+0.72^c \pm 22$		74Hu01 (69He11)	IMPAC	#See $^{110}\text{Cd}(656)$ , 74Hu01	
$^{114}_{48}\text{Cd}$	558	9.0ps	[2]	$+0.89 12$		67Bh03	IPAC	$\omega\tau=+9.69 106\text{mr}$	Cd in Fe; $H_{\text{int}}=348 10\text{kG}$
$^{114}_{48}\text{Cd}$	558	9.0ps	[2]	$+0.64 26$		69He11	IMPAC	$\Delta\theta=-5.2 25\text{mr}$	( $^{114}\text{Cd}$ on Fe)( $^{16}\text{O}, \text{O}'$ ); $H_{\text{int}}=-348 10\text{kG}$
$^{114}_{48}\text{Cd}$	558	9.0ps	[2]	$+0.62^c \pm 38$		74Hu01 (69He11)	IMPAC	#See $^{110}\text{Cd}(656)$ , 74Hu01	
$^{116}_{48}\text{Cd}$	513	13.7ps	[2]	$+1.42 76$		69He11	IMPAC	$\Delta\theta=-4.0 19\text{mr}$	( $^{116}\text{Cd}$ on Fe)( $^{16}\text{O}, \text{O}'$ ); $H_{\text{int}}=-348 10\text{kG}$
$^{116}_{48}\text{Cd}$	513	13.7ps	[2]	$+0.80^c \pm 62$		74Hu01 (69He11)	IMPAC	#See $^{110}\text{Cd}(656)$ , 74Hu01	

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat – Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{114}_{49}\text{In}$	gs	72s	[1]	$\leq \pm 1.7 \pm 4$		62Ko16	BAP		In–Fe alloy; $H_{\text{int}} \geq 250\text{kG}$ ; $H_{\text{int}}$ negative
$^{116}_{49}\text{In}$	gs	14s	[1]	$\pm 1.12$	$\sim \pm 0.03$	66Ra17	BAP	‡Assumed allowed $\beta$ -decay	$^{115}\text{In}$ (polarized n, $\gamma$ ); measured relaxation times in $\text{InF}_3$ , $\text{In}_2\text{O}_3$ , $\text{InP}$ , and $\text{In}$ –metal
$^{116}_{49}\text{In}$	gs	14s	[1]	$\pm 2.7860^d 12$	$\pm 0.09 \pm 2$	71Wil2	BAP–NMR	$\gamma/2\pi = 2.1132 \text{ 8kHz/G}$	$\text{InP}(\text{polarized th n, } \beta)$ at 77°K dependence of $\tau_{\text{relax}}$ ; used
$^{117}_{49}\text{In}$	660	60ns	[3/2]	$+0.95 8$		67Pa16	DPAC	$Q^{115} = +0.83\text{b}$	$^{116}\text{CdO}(\text{pile n, } \beta)$ ; $H_o = 8.6\text{kG}$
$^{117}_{49}\text{In}$	660	60ns	[3/2]		$\pm 0.64 \pm 4$	72Ra27	DPAC	$\nu_Q = 32.1 \text{ 5MHz}$	$\text{In}_{0.99}\text{Cd}_{0.01}$ at 4.2°K and 295°K; used $\nu_Q^{115} = 43.2 \text{ 1MHz}$ and $Q^{115} = 0.861 \pm 15\%$
$^{114}_{50}\text{Sn}$ or 3090	3210	700ns	[9] or [7]	$g = -0.081^{dp} 3$		72Bo44	DPAD		molten $^{112}\text{Cd}(\alpha, 2n)$ ; used $K \sim -0.8\%$
$^{115}_{50}\text{Sn}$	619	3.3μs	[7/2]	$< \pm 0.98 \pm$		71Br03	PAD–NMR	‡Searched for resonance in range $0.15 <  g  < 0.8$	liquid In metal(pulsed p,n)
$^{115}_{50}\text{Sn}$	726	159μs	[11/2]	$\pm 1.361 \pm 4$		71Br03	PAD–NMR	$\nu, B_0 = 100.03 \pm 530\text{G}; 274.52 \pm 1450\text{G}; 274.52 \pm 1460\text{G}$	liquid In metal(pulsed p,n) $H_o = 14, 35, 47\text{G}$ , $\tau_{\text{relax}} = 0.75 \text{ 18ms}$
$^{115}_{50}\text{Sn}$	726	159μs	[11/2]	$-1.32 \pm 11$		71Iv04	DPAC	‡kHz	liquid $^{113}\text{Cd}(\text{pulsed } \alpha, 2n)$ ; liquid $^{114}\text{Cd}(\text{pulsed } \alpha, 3n)$ ; $H_o = 6.48\text{G}$
$^{115}_{50}\text{Sn}$	726	159μs	[11/2]	$\pm 1.40 8$		72Me15	DPAD	$\nu = 7.81 \text{ 37kHz}$	In(pulsed p, ); $H_o = 0$ during pulse, $H_o = 40 \text{ 1G}$ between pulses
$^{115}_{50}\text{Sn}$	726	159μs	[11/2]		$\pm 0.8^p 3$	72Ri13	‡	‡Measured relaxation times as $f(T)$ by GAO	liquid In(pulsed p,n)
$^{116}_{50}\text{Sn}$	2369	350ns	[5]	$-0.325 \pm 25$		66RG02	DPAC		Sb dissolved in HCl; $H_o = 30.2\text{kG}$
				$-0.30 \pm 4$ or $-0.4 \pm 2$			IPAC	$G_2 \omega \tau = 312 \pm 43\text{mr}$	$H_o = 2.09\text{kG}$ ; $G_2 = 1$ or $0.7 \pm 3$
$^{118}_{50}\text{Sn}$	2320	21.7ns	[5]	$-0.340 \pm 14$		62Bo16	IPAC	$\omega \tau = 417 \pm 38\text{mr}$	$^{118}\text{Sb}$ in 3N HCl; $H_o = 40.95\text{kG}$
$^{118}_{50}\text{Sn}$	2320	21.7ns	[5]	$-0.300 \pm 25$		64De19	DPAC		Sb diffused into Fe foils; $H_{\text{int}} = 78.5 \pm 30\text{kG}$ , determined by Möss. on $^{119}\text{Sb}$
$^{120}_{50}\text{Sn}$	2300	5.5ns	[5]	$-0.37 5$		62Bo16	IPAC	$\omega \tau = 150 \pm 20\text{mr}$	$^{120}\text{Sb}$ in 3N HCl, $H_o = 53.2\text{kG}$
$^{120}_{50}\text{Sn}$	2300	5.5ns	[5]	$-0.280 \pm 25$		64De19	DPAC		Sb diffused into Fe foils; $H_{\text{int}} = 78.5 \pm 30\text{kG}$ , determined by Möss. on $^{119}\text{Sb}$
$^{120}_{50}\text{Sn}$	2300	5.5ns	[5]		$\pm 0.021 \pm 8$	70Wo02	DPAC	$\nu_Q = 1.15 \pm 4\text{MHz}$ $\nu_Q = 0.68 \pm 7\text{MHz}$ $Q/Q^{119}(23.8\text{keV}) = \pm 2.86 \pm 15$ , using interaction constants obtained by Mossbauer for $^{119}\text{Sb}$ in the same compounds	K $\text{SbC}_4\text{H}_4\text{O}_7$ / (SbO) $_2\text{SO}_4$
								‡Using $Q^{119}(23.8\text{keV}) = 0.06 \pm 2$	
$^{117}_{51}\text{Sb}$	3130	340μs	[21/2?]	$+1.21 \pm 16$		71Iv04	DPAD		liquid $^{115}\text{In}(\text{pulsed } \alpha, 2n)$ ; $H_o = 30$ to 100G
$^{117}_{51}\text{Sb}$	3130	340μs	[21/2?]	$\pm 1.22 \pm 3$		72Me15	DPAD	$\nu = 3.54 \pm 3\text{kHz}$	In(pulsed $\alpha, 2n$ ); $H_o = 0$ during pulse, $H_o = 40 \text{ 1G}$ between pulses

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat — Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{122}\text{Sb}$	gs	2.73d	(2)	$\pm 1.9\ 2$		71Kr15	GAP	Sb-Fe(pile n, )	
$^{122}\text{Sb}$	61	$1.8\ \mu\text{s}$	[3]	$+2.979^{\text{dp}}\ 12$		72He26	Strob	molten $^{122}\text{Sn}(p,n)$	
$^{124}\text{Sb}$	gs	60d	(3)	$\pm 1.26\ 7$		68Kn02	GAP	$\mu H=240\ 29,\ 270$	$^{124}\text{Sb}$ in Fe, 3 different
								$19,\ 305\ 24\text{nm-kG}$	sources; $H_{\text{int}}=218\ 5\text{kG}; T$
									measured by $^{60}\text{Co}$ and $^{124}\text{Te}$
									$\gamma$ -anisotropy
$^{124}\text{Sb}$	gs	60d	(3)	$\pm 1.42\ 10$		70Si17	GAP	$^{124}\text{Sb} + ^{54}\text{Mn}$ in Fe foil;	
								$H_{\text{hf}}=230\text{kG}; T=8\text{m}^\circ\text{K}; T$ mea-	
								sured by $^{54}\text{Mn}$ $\gamma$ -anisotropy	
$^{125}\text{Sb}$	gs	2.7y	(7/2)	$\pm 3.55^{\text{p}}\ 30$		64He08	GAP	$^{125}\text{Sb} + ^{54}\text{Mn}$ in Fe foil;	
								$H_{\text{int}} \approx 200\text{kG}, T=0.024^\circ\text{K}$	
$^{125}\text{Sb}$	gs	2.7y	(7/2)			68An05	GAP	$^{125}\text{Sb} + ^{60}\text{Co}$ diffused in Fe;	
								$H_{\text{int}}(\text{at Co})=286.3\text{kG}$ assumed	
$^{125}\text{Sb}$	gs	2.7y	7/2 $\ddagger$	$\pm 2.62\ 6$		68Ba70	GAP-NMR	$\gamma/2\pi=$	$^{125}\text{Sb}$ in Fe at $0.015^\circ\text{K}$ ;
								obtained $g$ from slope of	
								$\nu$ vs $H_o$ ; $H_{\text{hf}}=+231\ 6\text{kG}$	
								#From $\mu(68\text{St16})$ and $g(68\text{Ba70})$	
$^{125}\text{Sb}$	gs	2.7y	(7/2)	$\pm 2.59\ 3$		68St16	GAP	Sb-Fe alloy; $H_{\text{int}}=+230\text{kG}$ ;	
								$^{60}\text{Co}$ used for thermometry	
$^{126}\text{Sb}$	gs	12.5d	[8]	$\pm 1.28\ 7$		72Kr15	GAP	$\Delta/T=\pm 0.094\ 5$	$^{125}\text{Sb}$ used for thermo-
								metry; $T=14.5\text{m}^\circ\text{K}$ ; $H_{\text{int}}=231\text{kG}$	
$^{127}\text{Sb}$	gs	3.9d	[7/2]	$\pm 2.59\ 12$		72Kr15	GAP	$\Delta/T=\pm 0.431\ 20$	$^{125}\text{Sb}$ used for thermo-
								metry; $T=14.5\text{m}^\circ\text{K}$ ; $H_{\text{int}}=231\text{kG}$	
$^{128}\text{Sb}$	gs	8.6h	[8]	$\pm 1.31\ 19$		72Kr15	GAP	$\Delta/T=\pm 0.087\ 13$	$^{125}\text{Sb}$ used for thermo-
								metry; $T=16\text{m}^\circ\text{K}$ ; $H_{\text{int}}=231\text{kG}$	
$^{120}\text{Te}$	560	9.3ps	[2]	$+0.42\ 12$		69Hell	IMPAC	$\Delta\theta=-15.6\ 36\text{mr}$	$(^{120}\text{Te on Fe})(^{16}\text{O},\text{O}')$ ; $H_{\text{int}}=$
								$+620\ 20\text{kG}$ from Möss.	
$^{120}\text{Te}$	560	9.3ps	[2]	$+0.58^{\text{e}}\ \ddagger 16$		74Hu01 (69Hell)	IMPAC	#Assumed $g_{\text{ave}}(2+)=0.30$ ; $H_{\text{hf}}(\text{IMPAC})=$	
								$+342\ 163\text{kG}$ , $\Phi_i=10.8\text{mr}$ ; included effect	
								of decays-in-flight	
$^{122}\text{Te}$	564	7.6ps	[2]	$+0.91\ 12$		66Au05	IPAC	$\omega\tau=15.4\ 15\text{mr}$	Te in Fe; $H_o=10\text{kG}$ ; $H_{\text{int}}=$
								$+620\ 20\text{kG}$ from Möss.	
$^{122}\text{Te}$	564	7.6ps	[2]	$+0.79\ 12$		66Jo06	IPAC	$\omega\tau=-13.2\ 13\text{mr}$	Sb diffused into Fe;
								$H_o=10\text{kG}$ ; $H_{\text{int}}=637\ 21\text{kG}$	
$^{122}\text{Te}$	564	7.6ps	[2]	$+0.62\ 6$		67Bh06	IPAC	$\omega\tau=10.5\ 10,$ $9.9\ 12,\ 7.0\ 14\text{mr}$	three different Sb-Fe
								sources; assumed $H_{\text{int}}=$	
								$+620\ 20\text{kG}$	
$^{122}\text{Te}$	564	7.6ps	[2]	$+0.70\ 14$		67Mu10	IPAC	$\omega\tau=11.5\ 20\text{mr}$	Sb-Fe(pile n, ); $H_{\text{int}}=600$
								25kG	
$^{122}\text{Te}$	564	7.6ps	[2]	$+0.48\ 12$		69Hell	IMPAC	$\Delta\theta=-15.8\ 12\text{mr}$	$(^{122}\text{Te on Fe})(^{16}\text{O},\text{O}')$ ; $H_{\text{int}}=$
								$+620\ 20\text{kG}$ from Möss.	
$^{122}\text{Te}$	564	7.6ps	[2]	$+0.64^{\text{e}}\ \ddagger 10$		74Hu01 (69Hell)	IMPAC	#See $^{120}\text{Te}(560)$ , 74Hu01	
$^{123}\text{Te}$	159	190ps	[3/2]	$\pm 0.72\ 12$		70Ro31	AAC	$\omega\tau=\pm 0.42\ 6\text{r}$ $G_2=\pm 0.774\ 42$	$^{123}\text{Te}$ implanted in Fe; $H_{\text{int}}=$
								$620\ 20\text{kG}$ from NMR for dilute	
								Te in Fe	
$^{123}\text{Te}$	248	117d	[11/2]	$-1.00^{\text{p}}\ 5$		72Va25	GAP		Te implanted in Fe by mass
								separator; $T<20\text{m}^\circ\text{K}$	
$^{123}\text{Te}$	440	?	?	$g=+0.22^{\text{p}}\ \ddagger 3$		70Bo48	IMPAC	$\omega\tau=-38.5\ 33\text{mr}$	$(^{123}\text{Te in Fe})(^{16}\text{O},\text{O}')$ ; $H_{\text{hf}}=$
								$620\ 20\text{kG}$ ; $H_{\text{eff}}=7.1\ 16\text{MG-ps}$	
								#Estimated $\tau$ from $^{125}\text{Te}$ data	
$^{123}\text{Te}$	506	?	?	$g=+0.032^{\text{p}}\ \ddagger 7$		70Bo48	IMPAC	$\omega\tau=-4.4\ 23\text{mr}$	$(^{123}\text{Te in Fe})(^{16}\text{O},\text{O}')$ ; $H_{\text{hf}}=$
								$620\ 20\text{kG}$	
								#Estimated $\tau$ from $^{125}\text{Te}$ data	

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat — Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{124}_{52}\text{Te}$	603	6.6ps	[2]	+0.39 8		67Bh06		$\omega\tau=-6.6 \pm 24$ or $-5.4 \pm 13\text{mr}$	$^{123}\text{Sb}-\text{Fe}(\text{pile n},)$ ; $H_{\text{int}}=620$ 20kG assumed ‡For $(1690\gamma)(603\gamma)$ or $(722\gamma)(603\gamma)$
$^{124}_{52}\text{Te}$	603	6.6ps	[2]	+0.70 16		67Mu06	IPAC	$\omega\tau=9.7$ 13mr	Sb in Fe; $H_{\text{int}}=+610$ 25kG from Möss., includes temperature correction
$^{124}_{52}\text{Te}$	603	6.6ps	[2]	+0.53 44		68Bo41	IPAC	$\omega\tau=7.5$ 44mr	(Sb in Fe)(pile n,); $H_{\text{int}}=627$ 20kG
$^{124}_{52}\text{Te}$	603	6.6ps	[2]	+0.42 10		69He11	IMPAC	$\Delta\theta=-12.9$ 9mr	$(^{124}\text{Te}$ on Fe) $(^{16}\text{O},\text{O}')$ ; $H_{\text{int}}=+620$ 20kG from Möss.
$^{124}_{52}\text{Te}$	603	6.6ps	[2]	+0.54 <sup>c</sup> ‡ 8		74Hu01 (69He11)	IMPAC	‡See $^{120}\text{Te}(560)$ ; 74Hu01	
$^{125}_{52}\text{Te}$	145	58d	[11/2]	$\pm 0.93$ 5		72Si21	GAP		$^{125}\text{Te}$ implanted in Fe by mass separator; $H_{\text{int}}=657$ 20kG; $T<20\text{m}^\circ\text{K}$
$^{125}_{52}\text{Te}$	321	695ps	[9/2]	-0.909 72		69Kn03	IPAC	$\omega\tau=81$ 33mr $\omega\tau=200$ 15mr	liquid $^{125}\text{SbCl}_3$ ; $H_o=19.1$ 1kG $^{125}\text{Sb}$ dissolved in Ni; $H_o=20.0$ 1kG, $H_{\text{int}}=205$ 10kG
$^{125}_{52}\text{Te}$	321	695ps	[9/2]	-0.918‡ 32		70Cr07	IPAC	For $(321\gamma)(177\gamma)$ : $\omega\tau=47.7$ 33, $179^{+44}_{-29}$ , $830^{+240}_{-570}\text{mr}$ For $(204\gamma)(177\gamma)$ : $\omega\tau=54.2$ 48, 47.8 48mr; $\omega\tau=52.8$ 25, 234 17mr	dilute solutions of $^{125}\text{Sb}$ in Cu, Ni, Fe; $H_{\text{int}}=51.5$ , 236, 679kG $[\text{SbCl}_4]^-$ , $[\text{SbCl}_6]^-$ in HCl; $H_o=51.5$ kG;
$^{125}_{52}\text{Te}$	321	695ps	[9/2]	-0.66 9		71Ro17	IPAC	‡From weighted average of $\omega\tau/H=0.976$ 30r/MG	$^{125}\text{Sb}$ in Cu, Ni; $H_{\text{int}}=51.5$ , 236kG
$^{125}_{52}\text{Te}$	443	21ps	[3/2]	+0.52 <sup>p</sup> 16		70Ro35	IMPAC	$\omega\tau=132$ 17mr, for two cascades	fission $^{125}\text{Sb}$ in Ni; $H_{\text{int}}=186$ 10kG assumed
$^{125}_{52}\text{Te}$	463	13ps	[5/2]	+0.58 27		71Ro37	IMPAC	$\omega\tau=-43.0$ 54mr	$(\text{Te in Fe})(^{16}\text{O},\text{O}')$ ; $H_{\text{hf}}=620$ 20kG; $H_{\pi}=7.1$ 16MG-ps
$^{125}_{52}\text{Te}$	463	13ps	[5/2]	+0.30 <sup>p</sup> 12		70Ro35	IMPAC	$\omega\tau=14$ 6mr	$^{125}\text{Sb}$ in Fe; $H_o=51.5$ kG, $H_{\text{int}}=679$ kG
$^{125}_{52}\text{Te}$	463	13ps	[5/2]	+0.79 30		71Ro37	IMPAC	$\omega\tau=-10.8$ 33mr	$(\text{Te in Fe})(^{16}\text{O},\text{O}')$ ; $H_{\text{hf}}=620$ 20kG; $H_{\pi}=7.1$ 16MG-ps
$^{125}_{52}\text{Te}$	463	13ps	[5/2]	+0.79 30		71Ro17	IPAC	$\omega\tau_{\text{ave}}=18.7$ 69mr $\omega\tau(1)=21$ 14mr, $\omega\tau(2)=15$ 8mr	fission $^{125}\text{Sb}$ in Fe; $H_{\text{int}}=620$ 20kG; (1)=(209 $\gamma$ )(428 $\gamma$ ), (2)=(172 $\gamma$ )(428 $\gamma$ )
$^{125}_{52}\text{Te}$	525	?	[7/2?]	negative		71Ro17	IPAC	$\omega\tau=+107$ 24mr	fission $^{125}\text{Sb}$ in Fe
$^{126}_{52}\text{Te}$	667	4.42ps	[2]	+0.50 14		69He11	IMPAC	$\Delta\theta=-13.1$ 25mr	$(^{126}\text{Te}$ on Fe) $(^{16}\text{O},\text{O}')$ ; $H_{\text{int}}=620$ 20kG
$^{126}_{52}\text{Te}$	667	4.42ps	[2]	+0.62 <sup>c</sup> ‡ 16		74Hu01 (69He11)	IMPAC	‡See $^{120}\text{Te}(560)$ , 74Hu01	
$^{127}_{52}\text{Te}$	gs	9.4h	[3/2]	$\pm 0.66^p$ 5		72Si31	GAO		
$^{127}_{52}\text{Te}$	89	109d	[11/2]	-0.91 <sup>p</sup> 5		72Va25	GAP		Te implanted in Fe by mass separator; $T<20\text{m}^\circ\text{K}$
$^{128}_{52}\text{Te}$	743	3.18ps	[2]	+0.42 12		69He11	IMPAC	$\Delta\theta=-10.1$ 20mr	$(^{128}\text{Te}$ in Fe) $(^{16}\text{O},\text{O}')$ ; $H_{\text{int}}=620$ 20kG
$^{128}_{52}\text{Te}$	743	3.18ps	[2]	+0.54 <sup>c</sup> ‡ 14		74Hu01 (69He11)	IMPAC	‡See $^{120}\text{Te}(560)$ , 74Hu01	
$^{129}_{52}\text{Te}$	gs	69m	[3/2]	$\pm 0.67^p$ 5		72Si31	GAO		
$^{129}_{52}\text{Te}$	106	34d	[11/2]	-1.15 <sup>p</sup> 5		72Va25	GAP		Te implanted in Fe by mass separator; $T<20\text{m}^\circ\text{K}$
$^{130}_{52}\text{Te}$	840	2.0ps	[2]	+0.50 14		69He11	IMPAC	$\Delta\theta=-10.6$ 22mr	$(^{130}\text{Te}$ in Fe) $(^{16}\text{O},\text{O}')$ ; $H_{\text{int}}=620$ 20kG
$^{130}_{52}\text{Te}$	840	2.0ps	[2]	+0.64 <sup>c</sup> ‡ 18		74Hu01 (69He11)	IMPAC	‡See $^{120}\text{Te}(560)$ , 74Hu01	

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat – Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{125}_{53}\text{I}$	188	35ns	[3/2]	$\pm 2.8^{\text{sp}} 12$		72Le32	PAC		gaseous I at normal pressure
$^{127}_{53}\text{I}$	58	1.92ns	[7/2]	$\pm 1.70^{\text{p}} 33$		65Ta14	IPAC		$H_o=12.8\text{kG}$
$^{127}_{53}\text{I}$	58	1.92ns	[7/2]	$\pm 2.02 15$		67Sv01	IPAC	$\omega\tau=216 15\text{mr}$	$^{126}\text{Te}$ in $\text{HNO}_3$ and in $\text{HCl}$ ; $H_o=28.1\text{kG}$
$^{127}_{53}\text{I}$	58	1.92ns	[7/2]	$\pm 2.78^{\text{p}} 23$		69Be78	IPAC		$H_o=100\text{kG}$
$^{127}_{53}\text{I}$	203	330ps	[3/2]	$\geq \pm 1.07$		67Sv01	IPAC	$\omega\tau=88 15\text{mr}$	$^{127}\text{Xe}$ in Al foil; $H_o=51.2\text{kG}$
$^{131}_{53}\text{I}$	150	0.95ms	[5/2]	$+2.77^{\pm} 50$		67Ta07	IPAC	$\omega\tau=97 12\text{mr}$	$^{131}\text{Te}$ in $\text{HCl}$ ; $H_o=13.2\text{kG}$
									†Assumed time-dependent perturbations small
$^{131}_{53}\text{I}$	1797	5.9ns	[9/2, 11/2?]	$-0.72 23,$ $-0.88 28$		67Ta07	IPAC	$G_2\omega\tau=73 16\text{mr}$	$^{131}\text{Te}$ in $\text{HCl}$ ; $H_o=12.8\text{kG}$ ;
								$g=-0.16 5$	$G_2=0.9 I$
$^{132}_{53}\text{I}$	49.7	0.95ns	[3]	$+2.22 30$		69Si06	IPAC	$\omega\tau=94.4 123\text{mr}$	$^{132}\text{Te}$ metal in $\text{HCl}$ ; $H_o=19.5\text{kG}$ , assumed $G_2=1$
$^{132}\text{Xe}$	668	7ps	[2]	$+0.92^{\text{p}} 42$		69Si09	IPAC	$\omega\tau=22.3 71\text{mr}$	$^{132}\text{Te}$ diffused in Fe; $H_{\text{hf}}=1040 20\text{kG}$
$^{131}_{55}\text{Cs}$	133	9.3ns	[5/2]	$+2.48 15$		64Br20	DPAC	$\omega=138 8\text{Mr/s} \ddagger$	$\text{BaCO}_3$ powder; $H_o=29.1 3\text{kG}$
								†Unit given as MHz	
$^{131}_{55}\text{Cs}$	133	9.3ns	[5/2]	$\pm 2.30^{\text{p}} 20$		69Be79	IPAC		$G_2=0.88 8$
$^{131}_{55}\text{Cs}$	133	9.3ns	[5/2]	$+1.97 12$		69Fe02	DPAC		$\text{Ba}(\text{NO}_3)_2$ in dilute $\text{HNO}_3$ ;
								$H_o=9.3, 18\text{kG}$	
$^{131}_{55}\text{Cs}$	133	9.3ns	[5/2]	$\pm 1.85^{\text{p}} 7$		72Ao01	DPAC		$^{130}\text{Ba}(\text{NO}_3)_2(\text{th n}, )$ , dis-
								solved in $\text{HCl}$ ; $H_o=15.9\text{kG}$	
$^{133}_{55}\text{Cs}$	81	6.31ns	[5/2]	$+3.1 3$		59Bo56	IPAC		$\text{BaCl}_2$ aqueous solution; $H_o=22.4\text{kG}$
$^{133}_{55}\text{Cs}$	81	6.31ns	[5/2]	$+3.25^{\text{d}} 15$		64Ag02	CDPAC		$\text{BaCl}_2$ ; delay time=22.9ns
$^{133}_{55}\text{Cs}$	81	6.31ns	[5/2]	$+3.7 8$		66He12	IPAC		$H_o \sim 10\text{kG}$
				$\pm 3.5 5$					
$^{133}_{55}\text{Cs}$	81	6.31ns	[5/2]	$\pm 3.55 40$		68Re05	DPAC		$H_o=24.2\text{kG}$
$^{133}_{55}\text{Cs}$	160	190ps	[5/2]	$+1.65 50$		59Bo56	IPAC	$\omega\tau=+21 6\text{mr}$	$\text{BaCl}_2$ aqueous solution; $H_o=24.2\text{kG}$
$^{133}_{55}\text{Cs}$	160	190ps	[5/2]	$+1.42 32$		65Ag01	IPAC	$\omega\tau=11.3 36\text{mr},$ $\omega\tau=17.8 34\text{mr}$	dilute $\text{BaCl}_2$ in $\text{H}_2\text{O}$ ; $H_o=15.16, 21.17\text{kG}$
$^{134}_{56}\text{Cs}$	11.2	47.0ns	[5]	$+3.32 6$		71Dr10	DPAC		$\text{CsCl}(\text{pile n}, )$ dissolved in $\text{H}_2\text{O}$ ; $H_o=9.9, 11.0\text{kG}$
$^{134}_{56}\text{Ba}$ or 1400	605 $\leq 30\text{ps}$	5ps $\leq 30\text{ps}$	[2] [4]	$\sim 0.006$ $\geq 0.002$		70Be50	PAC	$\omega\tau=0.05 3\ddagger$	$^{134}\text{CsCl}$ aqueous solution, $H_o=41.4\text{kG}$
								†Unit not given, appears to be $10^{-1}\text{mr}$	
$^{137}_{56}\text{Ba}$	662	2.55m	[11/2]		negative $\sim 0.05$	65Lu02	GAO	$ Q  \approx  Q(^{137}\text{Cs}) $	Co–Cs Tutton salt, Cu–Cs Tutton salt
$^{133}_{57}\text{La}$	535	49ns	[11/2 $\ddagger$ ]	$\pm 7.7$		69Ge06, 70Ge14	DPAC		liquid sources $\text{Ce}^{2+}$ or $\text{Ce}^{3+}$ , $\text{La}^{2+}$ ; $H_o=4\text{kG}$
								†Author's original value, $I=3/2$	
$^{140}_{57}\text{La}$	gs	40.2h	(3)		+0.092 13 +0.115 16 +0.104 $\ddagger$ 10	66Bl05	GAO	$P=$ $+0.110 16 \times 10^{-4}/\text{cm}$ $-1.42 12 \times 10^{-5}/\text{cm}$	CMN at $1/T \sim 500$ NES at $1/T \sim 88$
								†Average, based on $Q^{139}=+0.22$	
$^{137}_{58}\text{Ce}$	gs	9.0h	(3/2)	$\pm 0.74 \ddagger 12$		63Ha07	GAO		NES, 1.2 to 4.2°K
								†Using $\langle r^{-3} \rangle = 4.44 \text{ au}$	
$^{137}_{58}\text{Ce}$	255	34.4h	(11/2)	$\pm 0.69 3$		66Bl17	GAO		NES, CMN; used $\langle r^{-3} \rangle = 4.44 \text{ au}$ and new temperature scale

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat — Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{139}_{58}\text{Ce}$	gs	140d	(3/2)	$\pm 0.95^{\pm} 20$		61Kn02	GAO		NES; $G_2=1$
$^{139}_{58}\text{Ce}$	gs	140d	(3/2)	$\pm 0.92 \pm 16$		62Gr17	GAO		NES, CMN
$^{139}_{58}\text{Ce}$	gs	140d	(3/2)	$\pm 0.78 \pm 16$		63Ha07	GAO	†Using $\langle r^{-3} \rangle = 4.44$ au	NES, CMN
$^{140}_{58}\text{Ce}$	2083	3.41ns	[4]	$\pm 4.60 \pm 32$		63Ka03	DPAC	†Using $\langle r^{-3} \rangle = 4.44$ au	La(NO <sub>3</sub> ) <sub>3</sub> in HNO <sub>3</sub> ; $H_o = 20.07$ 10kG
$^{140}_{58}\text{Ce}$	2083	3.41ns	[4]	+4.44 16		63Ko07	DPAC	†Average for two different cascades	
				$\pm 4.40 \pm 20$			IPAC	$\omega = 210$ 5Mr/s	liquid La(NO <sub>3</sub> ) <sub>3</sub> in 3N HNO <sub>3</sub> ; $H_o = 39.5$ kG
$^{140}_{58}\text{Ce}$	2083	3.41ns	[4]	$\pm 3.80 \pm 40$		64Sc16	DPAC	$\omega = 63.4$ 27Mr/s,	La(NO <sub>3</sub> ) <sub>3</sub> in 3N HNO <sub>3</sub> ; LaCl <sub>3</sub> + FeCl <sub>3</sub> in 2N HNO <sub>3</sub> ; $H_o = 12.1$ kG
$^{140}_{58}\text{Ce}$	2083	3.41ns	[4]	+4.06 15		65Le16	DPAC	La(OH) <sub>3</sub> in Ce(HSO <sub>4</sub> ) <sub>4</sub> ; $H_o = 16.5, 20, 24.5$ kG; $\beta = 1$	
$^{140}_{58}\text{Ce}$	2083	3.41ns	[4]		$\pm 0.404^* 80$	73Kl17	DPAC	$\nu_Q = 1.17$ 15MHz	La <sub>2</sub> Mg <sub>3</sub> (NO <sub>3</sub> ) <sub>12</sub> *24; used $Q(^{139}\text{La}) = +0.230$ 10b
$^{141}_{58}\text{Ce}$	gs	33d	(7/2)	$\pm 1.0 \pm 1$		62Gr17	GAO		Ce in NES
$^{141}_{58}\text{Ce}$	gs	33d	(7/2)	$\pm 1.10 \pm 16$		55Ca48		†Using $\langle r^{-3} \rangle = 4.44$ au	Ce in NES and CMN
$^{143}_{58}\text{Ce}$	gs	34h	(3/2)	$\sim \pm 1 \pm$		63Ha07, 72Sh01	GAO	†Using $\langle r^{-3} \rangle = 4.44$ au	$^{143}\text{Ce}$ in NES and CMN
								†Using $\langle r^{-3} \rangle = 4.44$ au. Analysis based on $I=7/2$ ; value not greatly affected by $I$	
$^{142}_{59}\text{Pr}$	gs	19.2h	(2)	$\pm 0.19$ or $\pm 0.14 \pm$		58Da12	GAO		Pr in CMN
$^{142}_{59}\text{Pr}$	gs	19.2h	(2)	$\pm 0.22 \pm$ or $\pm 0.14 \pm 1$		62Li06		†For $\Delta I_\beta = 1$ or 0	$^{142}\text{Pr}$ in CMN
$^{142}_{59}\text{Pr}$	gs	19.2h	(2)	negative <sup>p</sup>		58Gr92	GAO	$A = 0.0027$ 3 or $0.0042 \pm 5\text{cm}^{-1}$	
$^{143}_{59}\text{Pr}$	57	4.17ns	[5/2]	+3.25 12		62Li06		†For $\Delta I_\beta = 1$ or 0	$^{142}\text{Pr}$ in Te
$^{143}_{59}\text{Pr}$	57	4.17ns	[5/2]	+2.58 20		70Hi14	BAO	$\mu B_{\text{eff}} \sim 0.8\text{a-ergs}$	metallic and liquid sources; $H_o \leq 58$ kG
$^{143}_{59}\text{Pr}$	57	4.17ns	[5/2]			64Ko15	DPAC	$\omega \tau = 0.377$ 26r	$^{143}\text{Ce}_2(\text{SO}_4)_3$ or $^{143}\text{Ce}(\text{SO}_4)_2$ in H <sub>2</sub> SO <sub>4</sub> ; $H_o = 6.3$ kG, $\beta = 2.00$ ; CeO <sub>2</sub> at 1400°K; $H_o = 5.3$ 2kG, $\beta = 1.1$
$^{143}_{59}\text{Pr}$	57	4.17ns	[5/2]	$\pm 2.68 \pm 28$		66Zm01	IPAC	$g\beta = +2.06 \pm 16$ ; $g\beta = 1.13 \pm 11$	cubic CeO <sub>2</sub> ; $H_o = 5.6, 8.5$ kG; $G_2 = 0.98$ , $\beta = 2.0$
						68Ta12	IPAC	$G_2 \omega \tau = 0.223$ 33, 0.39 11r	dilute CeCl <sub>3</sub> ; $H_o = 2.8, 5.6, 8.5$ kG; $G_2 = 0.80$ 4, $\beta = 1.42$
								$G_2 \omega \tau = 145$ 20, 284 64, 404 96mr	
$^{144}_{60}\text{Nd}$	695	3.4ps	[2]	+0.26 4		72Ku10	IMPAC	$\Delta \theta = -11$ 2mr, corrected for beam-bending	CEx with $^{16}\text{O}^{5+}$ on $^{144}\text{Nd}$ , recoils in Fe; $H_o = 1.4$ kG, $H_{\text{int}} = 2.4$ 3MG; $H_{\tau} = 10.8$ 89MG-ps at 300°K
$^{144}_{60}\text{Nd}$	1314	90ps	[4]	+0.18 19		67Joll	IPAC	$g/g_{2+}^{150} = 0.40 \pm 10$	PmCl <sub>3</sub> in H <sub>2</sub> O; $H_o = 51.8$ 5kG; used $\beta = 2.25$

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat – Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{146}_{60}\text{Nd}$	454	21ps	[2]	$\pm 0.51 \pm 5$		68Be42	IMPAC	$g/g_{2+}(^{152}\text{Sm}) = 0.735 \pm 77$ †Used $g/g_{2+}^{148} = 1.2$	CEx with O, recoils in He, Ar; $H_o \sim 25.5 \text{ MG}$
$^{146}_{60}\text{Nd}$	454	‡	[2]	$+0.44 \pm 6$		72Ku10	IMPAC	$\Delta\theta = -83 \text{ mr}$ corrected for beam-bending $g/g_{2+}^{150} = 0.69 \pm 14$ † $T_{1/2} = 19.4 \text{ ps}$ used in analysis	[67Be08]; $g_{2+}(^{152}\text{Sm}) = 0.35$ CEx with $^{16}\text{O}^{5+}$ on $^{146}\text{Nd}$ , recoils in Fe; $H_o = 1.4 \text{ kG}$ , $H_{int} = 2.4 \text{ JMG}$ , $H\tau_i = 10.8 \text{ JMG-ps}$ at 300°K
$^{148}_{60}\text{Nd}$	300	116ps	[2]	$+0.48 \pm 10$		67Be08	IMPAC	$\omega\tau = 6.9 \text{ J2mr}$ $\omega\tau = 0.36 \pm 3, 0.24 \pm 2, 0.021 \pm 2$	$\text{Nd}^{3+}(^{16}\text{O}, \text{O}')$ recoils in Cu; $H_o = 16.6 \text{ kG}$ , $\beta(320^\circ\text{K}) = 2.17 \pm 17$
$^{148}_{60}\text{Nd}$	300	116ps	[2]	$\pm 0.43 \pm 3$		68Be42	AAC	$g/g_{2+}(^{152}\text{Sm}) = 0.61 \pm 4$ †Used $g_{2+}(^{152}\text{Sm}) = 0.35$	CEx with O, recoils in gas
$^{148}_{60}\text{Nd}$	300	116ps	[2]	$\pm 0.412 \pm 32$		70Be36	AAC	$\omega^2\tau_e = 0.079 \text{ J2r}^2/\text{ns}$ $g/g_{2+}^{150} = 0.638 \pm 52$	CEx recoils in He;
$^{148}_{60}\text{Nd}$	300	‡	[2]	$+0.50 \pm 8$		72Ku10	IMPAC	$\Delta\theta = -0.38 \pm 4$ corrected for beam-bending $g/g_{2+}^{150} = 0.80 \pm 18$ † $T_{1/2} = 85.2 \text{ ps}$ used in analysis	CEx with $^{16}\text{O}^{5+}$ on $^{148}\text{Nd}$ , recoils in Fe; $H_o = 1.4 \text{ kG}$ , $H_{int} = 2.4 \text{ JMG}$ , $H\tau_i = 10.8 \text{ JMG-ps}$ at 300°K
$^{150}_{60}\text{Nd}$	132	1.52ns	[2]	$+0.48 \pm 8$		58Ge72	IPAD	$\omega\tau = 94.5 \text{ J5mr}$	CEx with $^1\text{H}$ on aqueous solution of $\text{Nd}(\text{NO}_3)_3$ in $\text{HNO}_3$ ; $H_o = 16.0 \text{ J3kG}$ , $\beta = 2.3 \pm 3$
$^{150}_{60}\text{Nd}$	132	1.52ns	[2]	$+0.620 \pm 42$		67Ku07	DPAC		CEx with $^1\text{H}$ on solid Nd metal, 930°C; $H_o = 25 \text{ kG}$ , $\beta = 1.32$
$^{150}_{60}\text{Nd}$	132	1.52ns	[2]	$\pm 0.694 \pm 24$		68Be42	AAC	$g/g_{2+}(^{152}\text{Sm}) = 0.99 \pm 5$ $\omega^2\tau_e = 0.194 \text{ J1r}^2/\text{ns}$ $\omega^2\tau_e = 0.103 \text{ J6r}^2/\text{ns}$	CEx with O, recoils in He, Ar, Kr
$^{150}_{60}\text{Nd}$	132	1.52ns	[2]	$\pm 0.644 \pm 18$		70Be36			recoils in He
$^{150}_{60}\text{Nd}$	132	1.52ns	[2]	$+0.68 \pm 10$		68Be51	IPAC		recoils in Ar
$^{150}_{60}\text{Nd}$	397	55.9ps	[4]	$+1.28 \pm 20$		70Be36			CEx recoils in Ar; $H_o = 17.4 \text{ J6kG}$
$^{150}_{60}\text{Nd}$	397	55.9ps	[4]	$+1.28 \pm 20$		72Ku10	IMPAC	$\Delta\theta = -0.31 \pm 3$ corrected for beam-bending $g/g_{2+}^{150} = 1.00$	CEx with $^{16}\text{O}^{5+}$ on $^{150}\text{Nd}$ , recoils in Fe; $H_o = 1.4 \text{ kG}$ , $H_{int} = 2.4 \text{ JMG}$ , $H\tau_i = 10.8 \text{ JMG-ps}$ at 300°K
$^{143}_{61}\text{Pm}$ gs	265d	[5/2 or 7/2]	[5/2 or 7/2]	$\pm 3.75 \pm 50$ or $\pm 3.9 \pm 5$		63Gr10	GAO	$A = \pm 0.029 \text{ Jcm}^{-1}$ $P'' = 0.0022 \text{ Jcm}^{-1}$ or $A = \pm 0.022 \text{ Jcm}^{-1}$ $P'' = 0.00125 \text{ J2cm}^{-1}$	Pm <sup>3+</sup> in NES CMN
$^{144}_{61}\text{Pm}$ gs	360d	[5 or 6]	[5 or 6]	$\pm 1.68 \pm 14$ or $\pm 1.75 \pm 14$		61Sh02	GAO	$A/k = \pm 0.0091^\circ\text{K}$ or $A/k = \pm 0.0079^\circ\text{K}$	Pm <sup>3+</sup> in NES; used $\langle r^{-3} \rangle = 36.8 \times 10^{24} \text{ cm}^{-3}$
$^{144}_{61}\text{Pm}$ gs	360d	[5 or 6]	[5 or 6]			63Gr10	GAO	$A = \pm 0.0065 \text{ Jcm}^{-1}$ $P'' = 0.00011 \text{ Jcm}^{-1}$ or $A = \pm 0.0056 \text{ Jcm}^{-1}$ $P'' = 7.3 \times 10^{-5} \text{ cm}^{-1}$	NES CMN
$^{147}_{61}\text{Pm}$ 91	2.55ns	[5/2]		$+3.42 \pm 50$		60Bo17	IPAC	$\omega\tau = +0.79 \text{ J1r}$	aqueous solution of $\text{NdCl}_3$ ; $H_o = 15 \text{ kG}$ , $\beta = 2.2$
$^{147}_{61}\text{Pm}$ 91	2.55ns	[5/2]		$\sim +3$		60Ma03		$G_2\omega\tau = -0.38 \pm 9$ where $0.5 < G_2 < 1.0$	$\text{Nd}_2\text{O}_3$ in alcohol; $H_o = 13 \text{ kG}$
$^{148}_{61}\text{Pm}$ gs	5.4d	(1)		$\pm 1.82 \pm 19$		63Gr10	GAO	$A = \pm 0.035 \text{ Jcm}^{-1}$ $P'' = +0.0033 \text{ Jcm}^{-1}$	NES CMN
$^{148}_{61}\text{Pm}$ 137	43d	[6]		$\pm 1.80 \pm 18$		63Gr10	GAO	$A = \pm 0.0058 \text{ Jcm}^{-1}$	NES

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat – Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{149}_{61}\text{Pm}$	gs	53h	(7/2)	$\pm 3.3\ 5$		63Cr10, (60Ch15)	GAO	$P''=0.00088\ 20\text{cm}^{-1}$	CMN
$^{149}_{61}\text{Pm}$	114	2.58ns	[5/2]	$\pm 2.34\ 30$		66Sv01	IPAC AAC	$\omega\tau=0.377\pm 66\text{r},$ $\omega\tau=1.81\pm 16\text{r}$	$\text{NdCl}_3$ in $\text{H}_2\text{O}; H_o=13.90\ 40,$ 51.6 5kG; used $G_2=0.81\ 3,$ $\beta=1.92$
$^{149}_{61}\text{Pm}$	114	2.58ns	[5/2]	$\pm 2.51\ 33$		69Ta08	IPAC	$G_2\omega\tau=394\ 106\text{mr},$ 223 36mr; 354 146mr	$^{149}\text{Nd}_2\text{O}_3$ in dilute HCl; $H_o=12.8, 8.5\text{kG}$ for $(424\gamma)(114\gamma);$ $H_o=12.8\text{kG}$ for $(542\gamma)(114\gamma);$ used $G_2=0.80\ 3, \beta=1.92$
$^{149}_{61}\text{Pm}$	114	2.58ns	[5/2]	$\pm 2.08^p\ 15$		70Be67, 69Be25	IPAC		$^{148}\text{Nd}(\text{th n, }),$ dissolved in aqua regia; used $G_2=0.81$
$^{149}_{61}\text{Pm}$	114	2.58ns	[5/2]	$\pm 1.95\ 20$		70Sell	IPAC	$G_2\omega\tau=0.37\ 3\pm$ or $G_2\omega\tau=0.39\ 14\pm$	$^{149}\text{Nd}_2\text{O}_3$ in HCl; $(542\gamma)(114\gamma)$ or $(424\gamma)(114\gamma);$ used $\beta=1.93$ and $G_2=0.878\ 31$
$^{149}_{61}\text{Pm}$	188	3.24ns	[3/2]	$+1.08^p\ 15$		70Be67	IPAC	#Unit not given	$^{148}\text{Nd}(\text{th n, }),$ dissolved in aqua regia, used $G_2=0.77$
$^{149}_{61}\text{Pm}$	188	3.24ns	[3/2]	$\pm 2.2\ 6$		70Sell	IPAC	$G_2\omega\tau=0.74\ 16\pm$ #Unit not given	$^{149}\text{Nd}_2\text{O}_3$ in HCl; used $\beta=1.93$ and $G_2=0.62\ 12$ calculated from data on 114 and 270keV levels; time-dependent interactions assumed
$^{149}_{61}\text{Pm}$	211	80ps	[5/2]	$+2.18^p\ 35$		70Be67	IPAC		$^{148}\text{Nd}(\text{th n, }),$ dissolved in aqua regia; used $G_2=1$
$^{149}_{61}\text{Pm}$	270	2.59ps	[7/2]	$+2.21^p\ 11$		70Be67, 69Be25	IPAC		$^{148}\text{Nd}(\text{th n, }),$ dissolved in aqua regia; used $G_2=0.84$
$^{149}_{61}\text{Pm}$	270	2.59ps	[7/2]	$\pm 3.64\ 20$		70Sell	IPAC AAC	$G_2\omega\tau=0.42\ 6\pm$ or $G_2\omega\tau=0.46\ 2\pm$ #Unit not given	$\text{Nd}_2\text{O}_3$ in HCl; $(268\gamma)(156\gamma)$ or $(268\gamma)(270\gamma);$ used $\beta=1.93$ and $G_2=0.781\ 18$
$^{145}_{62}\text{Sm}$	gs	340d	[7/2]	$\pm 0.92\ 6$		69Ka21	GAO	$\mu/\mu^{147}=1.12\ 11,$ 1.15 12	NES, CMN
$^{147}_{62}\text{Sm}$	121	780ps	[5/2]	$-0.30\ 18$		68Bo47	IPAC		aqueous $\text{EuCl}_3; H_o=18.3\ 3\text{kG};$ used $\beta=1.16$
$^{147}_{62}\text{Sm}$	121	780ps	[5/2]	$-0.26^p\ 15$		70Be67	IPAC		$\text{Sm}(p, ); G_2=1$
$^{147}_{62}\text{Sm}$	198	1.31ns	[3/2]	$-0.28\ 10$		68Bo47	IPAC		aqueous $\text{EuCl}_3; H_o=18.3\ 3\text{kG};$ used $\beta=1.16$
$^{147}_{62}\text{Sm}$	198	1.31ns	[3/2]	$-0.28^p\ 6$		70Be67	IPAC		$\text{Sm}(p, ); G_2=1$
$^{148}_{62}\text{Sm}$	551	7.35ps	[2]	$+0.34\ 9$		72Ku10	IMPAC	$\Delta\theta=-30\ 2\text{mr}$ $g/g_{2+}^{154}=0.752\ 88$	CEx with $^{16}\text{O}^{5+}$ on $^{148}\text{Sm},$ recoils in Fe; $H_o=1.4\text{kG}, H_{int}=$ +2.3 2MG, $H_{rf}=10.8\ 89\text{MG-ps}$ at 300°K
$^{150}_{62}\text{Sm}$	334	48ps	[2]	$\pm 0.636\ 34$		70Be36 (68Be42)	AAC	$\omega^2\tau_c=0.177\ 19\text{r}^2/\text{ns}$ $g/g_{2+}^{152}=0.936\ 60$	CEx recoils in He gas
$^{150}_{62}\text{Sm}$	334	48ps	[2]	$+0.55\ 6$		72Ku10	IMPAC	$\Delta\theta=-22.6\ 11\text{mr}$ $g/g_{2+}^{154}=0.903\ 98$	CEx with $^{16}\text{O}^{5+}$ on $^{150}\text{Sm};$ see $^{148}\text{Sm}(551), 72\text{Ku01}$
$^{151}_{62}\text{Sm}$	105	480ps	[5/2]	$+0.52^p\ 18$		71Be23	IPAC		$^{150}\text{Nd}(\text{pile n, });$ used $\beta=1.16$ at 320°K; $G=1$
$^{151}_{62}\text{Sm}$	168	760ps	[3/2]	$+0.57^p\ 12$ $+0.58^p\ 12$		71Be23	IPAC		$^{150}\text{Nd}(\text{pile n, });$ used $\beta=1.16$ at 320°K; $G=1$
$^{152}_{62}\text{Sm}$	122	1.4ns	[2]	$\pm 0.62\ 12$		58Go72	IPAD	$\omega\tau=56.8\ 40\text{mr}$	CEx with $^1\text{H}$ on aqueous solu- tion of $\text{Sm}(\text{NO}_3)_3$ in $\text{HNO}_3;$ $H_o=16.0\ 3\text{kG}, \beta=1.16$
$^{152}_{62}\text{Sm}$	122	1.4ns	[2]	$+0.72\ 32$		58Su55	PAC		CEx with $^1\text{H}$ on $\text{Sm}_2\text{O}_3$ on Cu foil; $H_o=22\text{kG}, G_2\sim 0.6$

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat — Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{152}_{62}\text{Sm}$	122	1.4ns	[2]	$\pm 0.23\ 15$ $\pm 0.64\pm 11$		60De16	IPAC	$\omega\tau=0.063\ 7\text{r}$	$\text{Eu}_2\text{O}_3$ in $\text{HNO}_3$ ; $G_2=1$ , $H_o=19.0\ 2\text{kG}$ ; $\beta=3.0$
								$\Delta\theta/H=-2.12\ 18\text{mr}/\text{kG}$	$\text{Eu}_2\text{O}_3$ , $H_o=22\text{kG}$ ; $G_2(300^\circ\text{K})=0.68\ 8$ or $G_2(1200^\circ\text{K})=0.55\ 7$
$^{152}_{62}\text{Sm}$	122	1.4ns	[2]	$\pm 0.56\ 14$		60Ma38	IPAC	$G_2\omega\tau=37\ 9\text{mr}$	$\pm$ Using $\beta=1.16$ for liquid source and $300^\circ\text{K}$ data
$^{152}_{62}\text{Sm}$	122	1.4ns	[2]	$+0.700\ 60$		62Ba38	IPAC		$\text{Eu}_2\text{O}_3$ in nitric acid; $H_o=12\text{kG}$
$^{152}_{62}\text{Sm}$	122	1.4ns	[2]	$+0.554\ 56$		67Wo06	DPAD		$G_2=1.00\ 13$ , $\beta=1.15$
$^{152}_{62}\text{Sm}$	122	1.42ns	[2]	$\pm 0.678\ 24$ $\pm 0.692\ 26$		70Be36 (68Be51, 68Be42)	AAC	$\omega^2\tau_e=0.202\ 14$ , $0.094\ 7\text{r}^2/\text{ns}$	$\text{EuCl}_3$ in $\text{HCl}$ , $300^\circ\text{K}$ , $\beta=1.15$ ; anhydrous $\text{EuCl}_3$ , $\sim 1200^\circ\text{K}$ , $\beta=1.04$ ; $H_o=23$ , $26\text{kG}$
$^{152}_{62}\text{Sm}$	122	1.42ns	[2]	$\pm 0.60\ 7$		71Do17	IPAC		$^{152}\text{Sm}$ powder(p,p'); $\beta(330^\circ\text{K})=1.135$
$^{152}_{62}\text{Sm}$	366	57ps	[4]	$+1.22\ 15$		72Ku10	IMPAC	$\Delta\theta=-0.313\ 10\text{mr}$ $g/g_{2+}^{154}=1.00$	CEx recoils in He, Ar
$^{154}_{62}\text{Sm}$	82	3.02ns	[2]	$+0.53\ 12$		58Go72	IPAC	$\omega\tau=110\ 8\text{mr}$	$\pm$ Using $\beta=1.15$ for dilute aqueous $^{152}\text{Eu}_2\text{Cl}_3$ ; $H_o=21.8\ 1\text{kG}$
$^{154}_{62}\text{Sm}$	82	3.02ns	[2]	$+0.576\ 58$		67Wo06	DPAD		three distinct cascades
$^{154}_{62}\text{Sm}$	82	3.02ns	[2]	$\pm 0.634\ 56$ $\pm 0.620\ 64$		70Be36 (68Be42)	AAC	$\omega^2\tau_e=0.079\ 14\text{r}^2/\text{ns}$ $g/g_{2+}^{152}=0.917\ 28$	see $^{148}\text{Sm}(551)$ , 72Ku01
$^{154}_{62}\text{Sm}$	267	165ps	[4]			67Bo32	IMPAC	$\omega\tau=-0.45^p\ 5\text{r}$ $g/g_{4+}^{152}=0.68^p\ 12$ , using	see $^{152}\text{Sm}(122)$ , 58Go72
$^{154}_{62}\text{Sm}$	267	165ps	[4]	$+1.35\ 14$		72Ku10	IMPAC	$\Delta\theta=-889\ 44\text{mr}$ $g/g_{2+}^{154}=1.07\ 12$	$^{154}\text{Sm}$ metal powder(p,p');
$^{154}_{62}\text{Sm}$	549	23.5ps	[6]	$+1.90\ 28$		72Ku10	IMPAC	$\Delta\theta=-141\ 10\text{mr}$ $g/g_{2+}^{154}=1.12\ 13$	$\beta(330^\circ\text{K})=1.135$
$^{147}_{63}\text{Eu}$	625	765ns	[11/2]	$+6.00\ 33$		70Kl07	DPAC	$\omega=2.73\ 16\text{Mr/s}$	CEx with $^{16}\text{O}$ on $^{154}\text{Sm}$ , $^{152}\text{Sm}$
$^{149}_{63}\text{Eu}$	497	$2.43\mu\text{s}$	[11/2]	$+6.05\ 16$		70Kl07	DPAC	$\omega=2.75\ 7\text{Mr/s}$	$T_{1/2}^{152}(4+)=57.3\text{ps}$
$^{153}_{63}\text{Eu}$	103	3.8ns	[3/2]	$+1.05^p\ 26$		71Be23	IPAC		$\text{CEx with } ^{16}\text{O}^+ \text{ on } ^{154}\text{Sm};$
$^{154}_{63}\text{Eu}$	gs	16y	(3)		$\pm 1.88\ 21$	62Ju06, 66Bl05	GAO	$Q/Q_{^{152}}^{152}=+0.62\pm 7$	see $^{148}\text{Sm}(551)$ , 72Ku01
$^{155}_{63}\text{Eu}$	105	400ps	[5/2]	$+2.47^p\ 27$		71Be23	IPAC		$\text{CEx with } ^{16}\text{O}^+ \text{ on } ^{154}\text{Sm};$
$^{152}_{64}\text{Gd}$	344	29ps	[2]			67Pr16	IPAC	$\omega\tau=+21^p\ 9\text{mr}$	see $^{148}\text{Sm}(551)$ , 72Ku01
$^{152}_{64}\text{Gd}$	344	29ps	[2]	$+1.16\ 22$		69Zm01	IPAC	$(\omega\tau)_{ave}=37.5\ 33\text{mr}$	$\beta(320^\circ\text{K})=0.55$
$^{152}_{64}\text{Gd}$	344	29ps	[2]	$\pm 0.856\ 62$		70Be36	AAC	$\omega^2\tau_e=0.378\ 55\text{r}^2/\text{ns}$ $g/g_{2+}^{154}=1.003\ 80$	$\pm 2.75\ 17$ and $Q^{152}/Q^{151}=1.1\ 1$
$^{154}_{64}\text{Gd}$	123	1.18ns	[2]	$\pm 0.72\ 12$		61St04	IPAC	$\omega=26.6\ 35\text{Mr/s}$	$\pm$ Using $P^{154}$ as corrected in [66Bl05]
$^{154}_{64}\text{Gd}$	123	1.18ns	[2]	$+0.74\ 8$		62Ba38	IPAC	$\omega=48\ 4\text{Mr/s}$	$^{154}\text{Sm}(\text{pile n, })$ ; used $G=1$ and
$^{154}_{64}\text{Gd}$	123	1.18ns	[2]			67Pr16	IPAC	$\omega\tau=+0.14^p\ 2\text{r}$	$\beta(320^\circ\text{K})=0.55$
$^{152}_{64}\text{Gd}$									$^{152}\text{Eu}$ in Fe
$^{152}_{64}\text{Gd}$									$\text{Eu-Gd metal}; H_{int}(85^\circ\text{K})=-320\ 15\text{kG}$
$^{152}_{64}\text{Gd}$									CEx recoils in He
$^{154}_{64}\text{Gd}$	123	1.18ns	[2]	$\pm 0.72\ 12$		61St04	IPAC	$\omega=26.6\ 35\text{Mr/s}$	$\text{GdCl}_3$ at $980^\circ\text{C}$ ; $H_o=15\text{kG}$ , $\beta=1.042$ ; $G_2=0.8$
$^{154}_{64}\text{Gd}$	123	1.18ns	[2]	$+0.74\ 8$		62Ba38	IPAC	$\omega=48\ 4\text{Mr/s}$	anhydrous $^{154}\text{EuCl}_3$ at $1300^\circ\text{K}$
$^{154}_{64}\text{Gd}$	123	1.18ns	[2]			67Pr16	IPAC	$\omega\tau=+0.14^p\ 2\text{r}$	$H_o=26\text{kG}$ , $\beta=1.042$ ; $G_2=0.93\ 1$
$^{154}_{64}\text{Gd}$									$^{154}\text{Eu}$ in Fe

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat — Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{154}_{64}\text{Gd}$	123	1.18ns	[2]	+0.90 10		70Be36 (68Be42)	CDPAC	$\omega(t_{\text{ave}})=28.1\ 41\text{mr}$	$^{154}\text{Gd}$ recoils in He; $H_o=17.4\ 6\text{kG}$ ; $t_{\text{ave}}=735\ 30\text{ps}$ ; for $t/\tau=1.043\ 48$ ; $G_2=0.838\ 15$ and $G_4=0.587\ 29$ CEx recoils in He,Ar
$^{154}_{64}\text{Gd}$	123	1.18ns	[2]	$\pm 0.854\ 28$			AAC	$\omega^2\tau_e=0.376\ 24$ , $0.161\ 13\text{r}^2/\text{ns}$	
$^{154}_{64}\text{Gd}$	123	1.18ns	[2]	$\pm 0.86\ 7$		70Wa26	AAC	$g/g_{2+}^{154}=1.11\ 8$ $G_2/G_2^{154}=1.23\ 17$	$^{154}\text{Eu}_2\text{O}_3$ and $^{156}\text{Eu}_2\text{O}_3$ in 1.0N $\text{HClO}_4$ ; assumed electric interaction negligible and $g_{2+}^{154}=0.389\ 11$ $^{154}\text{Eu}$ in Fe
$^{154}_{64}\text{Gd}$	371	39ps	[4]			67Pr16	IPAC	$\omega\tau=+15^\text{p}\ 4\text{mr}$	
$^{155}_{64}\text{Gd}$	87	6.66ns	(5/2)	$\pm 0.73^{+12}_{-10}$ $\pm 0.90^{+23}_{-10}$		64Bo16 66Hr02	AAC	$g/g_{2+}^{152}=\pm 0.53\ 27$ $A=20.6^{+36}_{-28}\text{MHz}$	$^{155}\text{TbCl}_3$ in $\text{H}_2\text{O}$ ; used $\mu_{\text{gs}}^{155}=0.254\ 2$ , $A_{\text{gs}}^{155}=11.9\ 4\text{MHz}$ †Internal field corrected for $H_o=28\text{kG}$
$^{155}_{64}\text{Gd}$	87	6.66ns	(5/2)	-0.97 <sup>d</sup> 23		66Hr02	IPAC	$\omega=+45.8\ 103\text{Mr/s}$	anhydrous $\text{TbCl}_3+\text{GdCl}_3$ at 1300°C; $H_o=23.7\text{kG}$ , $\beta=1.044$
$^{155}_{64}\text{Gd}$	87	6.66ns	(5/2)	-0.92 <sup>p</sup> 10		71Be23	IPAC	$\omega=+45.3\ 33\text{Mr/s}$	$\text{Gd(p, )}$ ; used $\beta(320^\circ\text{K})=1.22$ ; $G=0.92\ 2$
$^{155}_{64}\text{Gd}$	105	1.1ns	(3/2)	+0.68 <sup>p</sup> 19		71Be23	IPAC		$\text{Gd(p, )}$ ; used $\beta(320^\circ\text{K})=1.22$ ; $G=1$
$^{156}_{64}\text{Gd}$	89	2.22ns	[2]	+0.64 6		62Ba38	IPAC	$\omega\tau=133\ 5\text{mr}$	anhydrous $^{156}\text{EuCl}_3$ at 1300°K $H_o=26\text{kG}$ , $\beta=1.042$ ; $G_2=0.89\ 2$ , $G_4=0.85\ 2$
$^{156}_{64}\text{Gd}$	89	2.22ns	[2]	+0.592 36		67Wo06	DPAD		CEx with $^1\text{H}$ on $^{156}\text{Gd}-\text{Cu}$ liquid metal at 1120°K, $\beta=1.086\ 15$
$^{156}_{64}\text{Gd}$	89	2.22ns	[2]	=0.680 26		70Be36	AAC	$\omega^2\tau_e=0.245\ 18\text{r}^2/\text{ns}$ $g/g_{2+}^{154}=0.807\ 39$	CEx recoils in He
$^{156}_{64}\text{Gd}$	288	115ps	[4]	$\pm 1.32^{+8}_{-48}$		67Bo32	IMPAC	$\omega\tau=0.087\ 20\text{r}$	CEx with $^{16}\text{O}$ on $^{156}\text{Gd}$ on Fe
$^{156}_{64}\text{Gd}$	288	115ps	[4]	+1.48 20		68We17	IPAC		$\text{Gd metal(d,2n)}$ at 77°K; $H_o \sim 13.2\text{kG}$ , $H_{\text{eff}}=-312\ 15\text{kG}$
$^{156}_{64}\text{Gd}$	1513	190ps	[4]	+3.12 20		68We17	IPAC	$g(1513)/g(288)=2.10\ 27$	$\text{Gd metal(d,2n)}$ or Tb metal( $\gamma,3\text{n}$ ) at 77°K; $H_o \sim 13.2\text{kG}$ , $H_{\text{eff}}=-312\ 15\text{kG}$
$^{158}_{64}\text{Gd}$	79.5	2.49ns	[2]	+0.630 50		67Wo06	DPAD		CEx with $^1\text{H}$ on $\text{Gd-Cu}$ liquid metal at 1120°K; $\beta=1.086\ 15$
$^{158}_{64}\text{Gd}$	79.5	2.49ns	[2]	$\pm 0.664\ 36$		70Be36	AAC	$\omega^2\tau_e=0.220\ 24\text{r}^2/\text{ns}$ $g/g_{2+}^{154}=0.765\ 48$	CEx recoils in He
$^{159}_{64}\text{Gd}$	gs	18h	(3/2)	$\pm 0.44\ 3$		71Kr19 70Pr13	GAP	$ \mu H/IkT =0.24\ 1$	$\text{GdFe}_2(\text{pile n, })$ ; $H_m=+453\text{kG}$ , $T=20\ 1\text{m}^\circ\text{K}$ ; sign of $\mu$ not measured
$^{160}_{64}\text{Gd}$	75	2.7ns	[2]	+0.606 52		67Wo06	DPAD		CEx with $^1\text{H}$ on $\text{Gd-Cu}$ liquid metal at 1120°K, $\beta=1.086\ 15$
$^{160}_{64}\text{Gd}$	75	2.7ns	[2]	$\pm 0.646\ 30$		70Be36	AAC	$\omega^2\tau_e=0.215\ 20\text{r}^2/\text{ns}$ $g/g_{2+}^{154}=0.756\ 43$	CEx recoils in He
$^{156}_{65}\text{Tb}$	gs	5.4d	(3)	$\pm 1.45\ 18$ $\pm 1.41^\circ 18$	+1.4 5 +1.40 <sup>e</sup> 45	62Lo01 63Bl25	GAO	$A/k=\pm 0.113\ 10^\circ\text{K}$ $P/k=+0.0045\ 15^\circ\text{K}$	Tb in NES
$^{159}_{65}\text{Tb}$	gs	—	(3/2)		+1.30	63Bl24 (62Lo12)	SpHt	$A/k=+0.150^\circ\text{K}$ $P/k=+0.021^\circ\text{K}$	Tb metal; $T=0.37$ to $4.2^\circ\text{K}$ ; used $\langle r^{-3} \rangle = 8.63\text{a.u.}$
$^{159}_{65}\text{Tb}$	gs	—	(3/2)		+1.32 <sup>e</sup> 10	63Bl25	SpHt		

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat – Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{159}_{65}\text{Tb}$	gs	–	(3/2)		(+0.82‡)	64Va27	SpHt	$A/k=+0.152\ 2^\circ\text{K}$ $P/k=+0.013\ 4^\circ\text{K}$	Tb metal; $T=0.05$ to $0.9^\circ\text{K}$
$^{159}_{65}\text{Tb}$	gs	–	(3/2)		(+0.99‡)	69Kr19	SpHt	$A/k=+0.149^\circ\text{K}$ $P/k=+0.0158^\circ\text{K}$	Tb metal; $T=0.03$ to $0.5^\circ\text{K}$
$^{160}_{65}\text{Tb}$	gs	72d	(3)	$\pm 1.60\ 25$ $\pm 1.56^\circ\ 25$	+1.9 5 +1.87°70	60Jo12 63Bl25	GAO	$A/k=+0.125\ 20^\circ\text{K}$ $P/k=+6.1\ 22\text{m}^\circ\text{K}$	Tb in NES at $0.02^\circ\text{K}$
$^{155}_{66}\text{Dy}$	gs	10h	[3/2]	$\pm 0.21\ 5$		61Na04	GAO	$A/k=0.032\ 8^\circ\text{K}$	Dy in NES at $0.02^\circ\text{K}$
$^{157}_{66}\text{Dy}$	gs	8.1h	[3/2]	$\pm 0.32\ 2$		61Na04	GAO	$A/k=0.048\ 3^\circ\text{K}$	Dy in NES at $0.02^\circ\text{K}$
$^{158}_{66}\text{Dy}$	630	?	[6]	$\pm 2.16\pm 42$		71Ka68	IMPAC		natural metallic Gd( $\alpha$ , ), at 77,170,257,300°K; finds $H_{\text{eff}} \sim 2.8, 2.3, 3.0, 0.0^\circ\text{MG}$ ; $H_{\tau} \sim$ 15°MG-ps from $\omega\tau(t)$
$^{160}_{66}\text{Dy}$	87	2.0ns	[2]	$\pm 0.48\ 14$ $\pm 0.54\pm 16$		60Ma38	IPAC	$\ddagger$ Assumed $g(6+)=g(8+)=g(2+)=0.36$ for $^{160,162}\text{Dy}$ $G_2\omega\tau=0.19\ 3\text{r}$	$\text{Tb}_2\text{O}_3$ in HCl at $340^\circ\text{K}$ ; $H_o =$ 12kG, $G_2=0.80\ 12$ , $\beta=6.0$
$^{160}_{66}\text{Dy}$	87	2.0ns	[2]	$\pm 0.83\ 9$ $\pm 0.99\pm 11$		61Ku03	IPAC	$\ddagger$ For $\beta=5.4$	$\text{Tb}_2\text{O}_3$ at 300,540,1333°K; $H_o =$ 18.3kG; used $\beta=7.2, 4.55, 2.4$
$^{160}_{66}\text{Dy}$	87	2.0ns	[2]	+0.58 18		62Co28	IPAC	$\omega\tau=-2.50\ 70\text{r}$	DyFeGarnet; used $H_{\text{eff}}=600\text{kG}$ from Mössbauer
$^{160}_{66}\text{Dy}$	87	2.0ns	[2]	$\pm 0.728\ 22$ +0.704 38		65Gu02	DPAC	$\omega=358\ 11\text{Mr/s}$	$\text{TbCl}_3$ in 3M HCl; $H_o = 33.5\text{kG}$ ,
					$\pm 5\ 1$	IPAC	$G_2\omega\tau=439\ 12\text{mr}$	$\beta=6.02$ for DPAC; $H_o = 20.19\text{kG}$ ,	
						AAC	$G_2=0.740\ 20$ , $G_4=$ 0.597 25	$\beta=6.07$ for IPAC	
$^{160}_{66}\text{Dy}$	87	2.0ns	[2]		$\pm 1.67\pm 36$ $\pm 1.76\pm 39$	69Fo08, 70Wa25	DPAC		$^{160}\text{Tb}$ in $\text{HClO}_4$ , $\text{H}_2\text{SO}_4$ , HCl; used $g=0.346\ 11$
$^{160}_{66}\text{Dy}$	87	2.05ns	[2]	$\pm 0.712\ 34$		70Be36	DPAC	$\ddagger Q(1-R)$	CEx recoils in He
$^{160}_{66}\text{Dy}$	966	2.2ps	[2]	+0.46°p 22		68Ca26	AAC	$\omega^2\tau_c=0.281\ 27\text{r}^2/\text{ns}$	magnetized Gd alloy
$^{160}_{66}\text{Dy}$	966	2.2ps	[2]	+0.36 12		69Si01	PAC		Dy in Tb metal, single crystal; $H_o = 13.6\text{kG}$ , $H_{\text{int}} =$ 5.6 4MG
$^{161}_{66}\text{Dy}$	26	28.4ns	(5/2)	+0.75°p 9 +0.78°p 9		71Be23	IPAC		$^{160}\text{Gd}(\text{pile n.})$ ; used $G=$ 0.38 10, $\beta(320^\circ\text{K})=5.7$
$^{161}_{66}\text{Dy}$	75	3.4ns	[3/2]	-0.35°p 5		71Be23	IPAC		$^{160}\text{Gd}(\text{pile n.})$ ; used $G=0.89$ $\beta(320^\circ\text{K})=5.7$
$^{162}_{66}\text{Dy}$	80.7	2.25ns	[2]	+0.724 48		67Ku07	DPAC		Dy-Cu eutectic liquid at 880°C(pulsed p,p'); $H_o = 25\text{kG}$ , $\beta=2.30$
$^{162}_{66}\text{Dy}$	80.7	2.25ns	[2]	$\pm 0.686\ 28$		70Be36	AAC	$\omega^2\tau_c=0.261\ 22$ , 0.100 14r <sup>2</sup> /ns $g/g_{2+}^{160}=0.964\ 62$	CEx recoils in He, Ar
$^{164}_{66}\text{Dy}$	73.3	2.39ns	[2]	+0.642 50		67Ku07	DPAC		Dy-Cu eutectic liquid at 880°C(pulsed p,p'); $H_o = 25\text{kG}$ , $\beta=2.30$
$^{164}_{66}\text{Dy}$	73.3	2.39ns	[2]	$\pm 0.730\ 30$		70Be36	AAC	$\omega^2\tau_c=0.296\ 24\text{r}^2/\text{ns}$ $g/g_{2+}^{160}=1.026\ 65$	CEx recoils in He
$^{165}_{67}\text{Ho}$	gs	stable	(7/2)			64Va27	SpHt	$A/k=+0.320\ 5^\circ\text{K}$ $P/k=+8.0\ 15\text{m}^\circ\text{K}$	Ho metal
$^{165}_{67}\text{Ho}$	gs	stable	(7/2)			69Kr19	SpHt	$A/k=+0.319^\circ\text{K}$ $P/k=+4\text{m}^\circ\text{K}$	Ho metal, $T=0.03$ to $0.5^\circ\text{K}$
$^{166}_{67}\text{Ho}$	9	1.2ky	[7]	$\pm 4.14\pm 17$		59Po62	GAO	$A/k=0.24\ 2^\circ\text{K}$ , for $I=7$	Ho in NES single crystal
								$\ddagger$ Used $\mu^{165}=4.12\ 2$ , $A^{165}/k=0.478\ 2^\circ\text{K}$	

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat – Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{156}_{68}\text{Er}$	344	47.9ps	[2]	$g_{av} \sim \pm 0.39$		70No01	AAC	$G_2(344)=0.23\ 4$ $G_2(453)=0.73\ 8$	$^{120}\text{Sn}(^{40}\text{Ar},\text{Ar}')$ recoils in vacuum; assumed $H \sim 41\ \text{MG}$ , $\tau_c=3\text{ps}$
	453	7.83ps	[4]	to $0.42\ddagger$					$\ddagger$ Depends on model used
$^{158}_{68}\text{Er}$	193	433ps	[2]	$g_{av} \sim \pm 0.34$		70No01	AAC	$G_2(193)=0.07\ 5$	$^{122}\text{Sn}(^{40}\text{Ar},\text{Ar}')$ recoils in vacuum; assumed $H \sim 41\ \text{MG}$ , $\tau_c=3\text{ps}$
	356	20.8ps	[4]	to $0.39\ddagger$				$G_2(356)=0.47\ 4$	
	434	4.04ps	[6]					$G_2(434)=0.93\ 8$	
$^{160}_{68}\text{Er}$	264	49.8ps	[4]	$g_{av} \sim \pm 0.26$		70No01	AAC	$G_2(264)=0.31\ 5$	$^{124}\text{Sn}(^{40}\text{Ar},\text{Ar}')$ recoils in vacuum; assumed $H \sim 41\ \text{MG}$ , $\tau_c=3\text{ps}$
	376	7.77ps	[6]	to $0.39\ddagger$				$G_2(376)=0.82\ 5$	
	465	4.04ps	[8]					$G_2(465)=1.08\ 9$	
$^{166}_{68}\text{Er}$	80.6	1.82ns	[2]	$\pm 0.56\ 10$		60Ma38	IPAC	$\omega\tau=0.14\ 2\tau$	$^{166}\text{Ho}$ in dilute $\text{HNO}_3$ ; $H_o=5\text{kG}$
				$\pm 0.62\ddagger\ 12$				$\ddagger$ For $\beta=7.0$	$\beta=7.7$ , $G_2=0.78\ 12$ , $G_4=0.55\ 5$
$^{166}_{68}\text{Er}$	80.6	1.82ns	[2]	$+0.520\ 68$		61Bo05	IPAC	$\omega=+140\text{Mr/s}$	$\text{HoCl}_3$ aqueous solution;
				$+0.614\ddagger 80$		63Ge09		$\ddagger$ For $\beta=7.08$	$H_o=13.55\text{kG}$ , $\beta=8.36$
$^{166}_{68}\text{Er}$	80.6	1.82ns	[2]	$\pm 0.71\ 12$		61Ku03	IPAC		$\text{Ho}_2\text{O}_3$ at 80, 300, 1333°K; used $\beta=25.2$ , 7.9, 2.6
				$\pm 0.76\ddagger\ 12$				$\ddagger$ For $\beta=25.5$ , 6.8, 2.35	
$^{166}_{68}\text{Er}$	80.6	1.82ns	[2]	$+0.658\ 54$		67Ku07	DPAC		Er–Cu eutectic liquid at 930°C(pulsed p,p'); $H_o=25\text{kG}$ , $\beta=2.48$
$^{166}_{68}\text{Er}$	265	120ps	[4]	$+1.08\ 10$		63Ge09	IPAC	$\omega\tau=83\ 6\text{mr}$ , corrected for other cascades	dilute aqueous $\text{HoCl}_3$ solution; $H_o=53\text{kG}$ , $\beta=7.08$
$^{166}_{68}\text{Er}$	265	120ps	[4]			68De28	IMPAC	$\omega\tau=0.60\ 5\tau$	CEx with $^{16}\text{O}$ on $^{166}\text{Er}$ on polarized Fe foil; find $H_{hf}=-2.2\ \text{3MG}$
$^{166}_{68}\text{Er}$	265	120ps	[4]	$\pm 1.18\ddagger 7$		72Mi21	IPAC	$\omega\tau/\beta=6.20\ 21\text{mr}$	$\text{Ho metal(n, )}; \text{HoCl}_3$ ; $H_o=25.4\ 3\text{kG}$
$^{168}_{68}\text{Er}$	79.8	1.91ns	[2]	$+0.50\ 6$		62Bo18	IPAC	$\omega\tau=485\ 51\text{mr}$	$\text{Tm}(\text{NO}_3)_3$ in 3N $\text{HNO}_3$ ; $H_o=20.3\text{kG}$ , $\beta(300^\circ\text{K})=7.26$
				$+0.53\ddagger 6$				$\ddagger$ For $\beta=6.82$	
$^{168}_{68}\text{Er}$	79.8	1.91ns	[2]	$+0.688\ 56$		67Ku07	DPAC		Er–Cu eutectic liquid at 930°C(pulsed p,p'); $H_o=25\text{kG}$ , $\beta=2.48$
$^{168}_{68}\text{Er}$	79.8	1.91ns	[2]	$\pm 0.610\ 20$		70Be36	AAC	$\omega^2\tau_c=0.199\ 13$ , $0.100\ 11\tau^2/\text{ns}$	CEx recoils in He, Ar
$^{168}_{68}\text{Er}$	264	120ps	[4]	$+1.08\ddagger 16$		68De28	IMPAC	$\omega\tau=0.60\ 5\tau$	CEx with $^{16}\text{O}$ on $^{168}\text{Er}$ on Fe foil; $H_{hf}=-2.2\ \text{3MG}$
$^{168}_{68}\text{Er}$	~7800	?	[4]	$-0.45\ 74$		70Be13	‡	$g/g_{4+}^{166}=1.00$ $\ddagger$ Used $g_{4+}^{166}=1.08\ 10$ $\Delta E=0\ 6\mu\text{eV}$	$^{167}\text{Er}$ metal crystal (polarized n, ); $H_{eff} \sim 6.2\text{MG}$ ; assumed $\mu^{167}=-0.56$
								$\ddagger$ Measured energy shift of neutron resonance in strong magnetic field	
$^{168}_{68}\text{Er}$	~7800	?	[3]	$\pm 5.9\ 12$		70Be13	‡	$\Delta E=-43.5\ 80\ \mu\text{eV}$	$^{167}\text{Er}$ metal crystal (polarized n,–); $H_{eff} \sim 6.2\text{MG}$ ; assumed $\mu^{167}=-0.56$
								$\ddagger$ Measured energy shift of neutron resonance in strong magnetic field	
$^{170}_{68}\text{Er}$	79	1.90ns	[2]	$+0.658\ 50$		67Ku07	DPAC		Er–Cu eutectic liquid at 930°C(pulsed p,p'); $H_o=25\text{kG}$ , $\beta=2.48$
$^{170}_{68}\text{Er}$	79	1.90ns	[2]	$\pm 0.714\ 30$		70Be36	AAC	$\omega^2\tau_c=0.273\ 23\tau^2/\text{ns}$ $g/g_{2+}^{168}=1.171\ 62$	CEx recoils in He

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat – Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{170}_{68}\text{Er}$	261	135ps	[4]	$\pm 1.25 \pm 21$		68De28	IMPAC	$\omega\tau=0.62$ 6r $g/g_{4+}^{16.6}=0.92$ †Used $g_{4+}^{16.6}=1.08$ 10	CEx with $^{16}\text{O}$ on $^{170}\text{Er}$ on Fe foil; $H_{hf}=-2.2$ 3MG
$^{169}_{69}\text{Tm}$	118	62ps	[5/2]	$+0.50$ 15 $+0.54 \pm 16$		60Ma38	IPAC	$G_2\omega\tau=5.6$ 17mr †For $\beta=5.2$	$^{169}\text{Yb}_2\text{O}_3$ in dilute $\text{HNO}_3$ ; $H_o=13\text{kG}$ , $\beta\sim 5.6$ , $G_2\sim 1$
$^{169}_{69}\text{Tm}$	118	62ps	[5/2]	$+0.61$ 12		65Bo08	PAC	$G_2\omega\tau=5.9$ 2mr	$\text{YbCl}_3$ in $\text{H}_2\text{O}$ ; $H_o=10.8$ 4kG, $\beta=5.31$ , $G_2=0.99$
$^{169}_{69}\text{Tm}$	118	62ps	[5/2]	$\pm 0.73 \pm 12$		66Ko01	IPAC	$g(139)/g(118)=1.28$ 12 †Used $g(139)=0.37$ 4	LuIG at liquid N temperature
$^{169}_{69}\text{Tm}$	118	62ps	[5/2]	$+0.79$ 8		68Ka14	IPAC	$\omega\tau=-21.8$ 22mr $\mu\tau=70.2$ 71nm-ps	$\text{Yb}_2\text{O}_3$ in HCl; $H_o=32.57$ 30kG, $\beta(308^\circ\text{K})=4.98$ , $G_2\sim 1$
$^{169}_{69}\text{Tm}$	118	62ps	[5/2]	$+0.72$ 8		69Gu01	IPAC	$\mu\tau=64.5$ 70nm-ps	$\text{YbCl}_3$ in 3N HCl; $H_o=22.0$ 6kG $\beta(300^\circ\text{K})=5.08$
$^{169}_{69}\text{Tm}$	139	320ps	[7/2]	$\pm 1.22$ 17		65Bo08	IPAC	$G_2\omega\tau=41.7$ 40mr	$\text{YbCl}_3$ in $\text{H}_2\text{O}$ ; $H_o=10.8$ 4kG, $\beta=5.31$ , $G_2=0.95$
$^{169}_{69}\text{Tm}$	139	320ps	[7/2]	$+1.30$ 7		68Ka14	IPAC	$\omega\tau=-133$ 4mr $\mu\tau=600$ 24nm-ps	$^{169}\text{Yb}_2\text{O}_3$ in HCl; $H_o=32.57$ 30kG, $\beta(308^\circ\text{K})=4.98$ , $G_2=0.956$ 12
$^{169}_{69}\text{Tm}$	139	320ps	[7/2]	$+1.28$ 8		69Gu01	IPAC	$\mu\tau=588$ 29nm-ps	$\text{YbCl}_3$ in 3N HCl; $H_o=22.0$ 6kG $\beta(300^\circ\text{K})=5.08$
$^{169}_{69}\text{Tm}$	139	320ps	[7/2]			72Be43	PAC AAC	$Q(139)/Q(118)=1.0^p$ 2	$^{169}\text{Yb}$ implanted in Fe
$^{169}_{69}\text{Tm}$	316	660ns	[7/2]	$\pm 0.154$ 8		72Ni03	DPAC	$\omega=6.30$ 35Mr/s	$^{169}\text{Yb}(\text{C}_2\text{H}_3\text{O}_2)_3$ solution; $H_o\sim 5.98\text{kG}$ , $\beta(300^\circ\text{K})=5.08$
$^{169}_{69}\text{Tm}$	379	36ns	[7/2]	$\pm 0.959$ 4p 74		67Ni05	DPAC	$\omega=85.1$ 34Mr/s	$\text{YbCl}_3$ in HCl; $H_o=12.87\text{kG}$ , $\beta=5.08$
$^{171}_{69}\text{Tm}$	117	55ps	[5/2]	$+0.81$ 37		68Ka14	IPAC	$\omega\tau=-20.2$ 80mr $\mu\tau=65$ 26nm-ps	$^{171}\text{Er}_2\text{O}_3$ in HCl; $H_o=32.57$ 30kG, $\beta(308^\circ\text{K})=4.98$ , $G_2\sim 1$
$^{171}_{69}\text{Tm}$	129	362ps	[7/2]	$+0.94$ 18		65Ag02	IPAC		$\text{ErCl}_3$ in $\text{H}_2\text{O}$ ; $H_o=21.47\text{kG}$ , $\beta(300^\circ\text{K})=5.08$ , assumed $G_2=1$
$^{171}_{69}\text{Tm}$	129	362ps	[7/2]	$+1.44$ 14		68Ka14	IPAC	$\omega\tau=-168$ 15mr $\mu\tau=756$ 67nm-ps	$^{171}\text{Er}_2\text{O}_3$ in HCl; $H_o=32.57$ 30kG, $\beta(308^\circ\text{K})=4.98$ ; $G_2=0.949$ 13
$^{169}_{70}\text{Yb}$	gs	32d	[7/2]	$\pm 0.63$ 9		72Kr18	GAO	$B_2=0.59$ 10 $\Delta/k=\pm 11.7$ 15m°K	$\text{Yb}-\text{Au}; H_{int}=1.77\text{MG}$ ; $T=18$ 2m°K
$^{170}_{70}\text{Yb}$	84	1.58ns	[2]	$+0.66$ 4		65Ti02	DPAD		CEx of $^{170}\text{Yb}$ metal target
$^{172}_{70}\text{Yb}$	78.7	1.6ns	[2]	$+0.608$ 68		64Gu01	PAC	$\omega\tau=305$ 31mr‡ †Unit not given	$\text{LuCl}_3$ in dilute HCl; $H_o=35.9$ kG, $\beta=2.58$ 10, $G_2=0.95$ 2
$^{172}_{70}\text{Yb}$	78.7	1.6ns	[2]	$+0.558$ 28	+2.7 7	66Ti01	DPAD		$^{172}\text{Yb}$ metal(p,p')
$^{172}_{70}\text{Yb}$	78.7	1.6ns	[2]			69Fo07	DPAC	$Q(1-R)=2.16$ 37b	$\text{Er}_2\text{O}_3$ in $\text{HClO}_4$ ; used $R\sim 0.2$ , $g=0.328$ 5
$^{172}_{70}\text{Yb}$	1174	7.95ns	[3]	$+0.67$ 4		70Wa25			$\text{LuCl}_3$ in 0.1M HCl; $H_o=28\text{kG}$ , $\beta=2.58$ 13
$^{172}_{70}\text{Yb}$	1174	7.95ns	[3]		$\pm 3.6 \pm 10$	65Gu01	IPAC	$\omega_o(1174)/\omega_o(79)=0.53$ 6 $Q(1174)/Q(79)=\pm 1.33$ 15 †Used $Q(79)=2.7$ 7	Yb in Tm metal; $\text{Tm}_2\text{O}_3$
$^{172}_{70}\text{Yb}$	1174	7.95ns	[3]		$\pm 3.6 \pm 10$	70Ra18	DPAC	$Q(1174)/Q(79)=1.32$ 14	$^{171}\text{Er}_2\text{O}_3$ in 1N $\text{HClO}_4$ , in 16.4N HCl at $-30^\circ\text{C}$ , and in ethyl alcohol at $+20^\circ\text{C}$ , $-84^\circ\text{C}$
$^{172}_{70}\text{Yb}$	1174	7.95ns	[3]	$+0.61$ 9		71Wa03	IPAC	$\omega\tau(1174)/\omega\tau(79)=3.01$ 33 †Used $Q(79)=2.7$ 7	used $g_{2+}^{17.2}=0.332$ 8 from Möss.

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat – Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{173}_{70}\text{Yb}$	79	38ps	[7/2]	-0.203 <sup>p</sup> 66		72Ka13	PAC		
$^{173}_{70}\text{Yb}$	179	36ps	[9/2]	+0.27 <sup>p</sup> 36		72Ka13	PAC		
$^{173}_{70}\text{Yb}$	351	0.45ns	[11/2]	-0.71 <sup>p</sup> 71		72Ka13	PAC		
$^{174}_{70}\text{Yb}$	76.5	1.79ns	[2]	+0.494 26		66Ti01	DPAD		
$^{175}_{70}\text{Yb}$	gs	4.2d	[7/2]	$\pm 0.15$ 4		57Gr51	GAO	$A/k=6.4\text{m}^\circ\text{K}$	$^{174}\text{Yb}$ metal(p,p') $\text{Yb}(\text{C}_2\text{H}_5\text{SO}_4)_3 \cdot 9$
$^{175}_{70}\text{Yb}$	gs	4.2d	[7/2]	$\pm 0.18$ 5		62Li06			
$^{175}_{70}\text{Yb}$				$\pm 0.23$ ‡ or 0.33‡	6† 2	71Sp16 (57Gr51)	GAO		ion implantation in YES; $H_{\text{eff}}=1.77\text{MG}$
$^{175}_{70}\text{Yb}$									ion implantation in Au
									‡For $\gamma$ -mixing ratio + or -
									†Assumed $H_{\text{eff}}=1.77\text{MG}$ as for YES
$^{175}_{70}\text{Yb}$	gs	4.2d	[7/2]	$\pm 0.40$ 5		72Kr18	GAO	$B_2=0.315$ 32	$\text{Yb}-\text{Au}; H_{\text{int}}=1.77\text{MG}; T=18\text{ 2m}^\circ\text{K}$
$^{176}_{70}\text{Yb}$	82	1.76ns	[2]	+0.598 30		66Ti01	DPAD		$^{176}\text{Yb}$ metal(p,p')
$^{175}_{71}\text{Lu}$	114	100ps	[9/2]	+1.5 5		60Ma03	IPAC	$G_2\omega\tau=-3.0$ 10mr	$^{174}\text{Yb}_2\text{O}_3$ in dilute $\text{HNO}_3$ ;
$^{175}_{71}\text{Lu}$	114	100ps	[9/2]	+1.81 20		65Ka05	IPAC	$\omega\tau=14.5$ 14mr	$H_o=13\text{kG}$ Yb metal from $\text{Yb}_2\text{O}_3$ (pile n), $H_o=52.25$ 50kG, assumed $\beta \sim 1$
				+1.99‡ 15		69Wa30		$\omega\tau=15.6$ 12mr $\omega\tau=17.5$ 16mr	$\text{Yb}(\text{NO}_3)_3$ in $\text{H}_2\text{O}$ ; $H_o=52.3$ 5kG $^{175}\text{YbIG}$
$^{175}_{71}\text{Lu}$	251	42ps	[11/2]	+1.9‡ 6		66De08	IPAC	‡Based on average $\omega\tau=15.86$ 85mr	$^{175}\text{Yb}$ in Fe foil
									‡Used $g^{175}(114)=+0.403$ 44 to obtain $H_{\text{int}}=$ -338 42kG
$^{177}_{71}\text{Lu}$	971	155d	[23/2]		+12.6 14	66Bl05	GAO	$Q/Q_g=+2.33$ 25	Lu in NES
$^{176}_{72}\text{Hf}$	88.4	1.40ns	[2]	+0.532 42		68Be04	IPAC	$\omega\tau=43.9$ 30mr	CEx recoils in liquid Ga; $G=0.982$ 23; $H_o$ not given
$^{177}_{72}\text{Hf}$	113	500ps	[9/2]	+0.82 22		60Ma03	IPAC	$G_2\omega\tau=-9.1$ 14mr	$\text{Lu}_2\text{O}_3$ in nitric acid; $H_o=$ 13kG; assumed $\beta=1$ , $G_2=1$
$^{177}_{72}\text{Hf}$	113	500ps	[9/2]	$\pm 1.14$ 15		62Bo27	IPAC	$\omega\tau/H=+0.824^d$ 25	$\text{Lu}(\text{NO}_3)_3+\text{H}_2\text{O}$ ; $H_o=26.30$ 24kG
$^{177}_{72}\text{Hf}$	113	500ps	[9/2]	+1.09 <sup>d</sup> 6		62Ma42	IPAC	mr/kG	dilute aqueous $\text{LuCl}_3$ (pile n) $H_o=29.2$ , 53.1kG; $G_2>0.98$ ( $H_{\text{int}}$ uncertain ~10%, 65Ma27)
$^{177}_{72}\text{Hf}$	113	500ps	[9/2]	$\pm 1.13$ 5		69Ni15	IPAC		$H_o=18.48\text{kG}$
$^{177}_{72}\text{Hf}$	250	98ps	[11/2]	+1.43 50 +2.6‡ 8		68Br15	IPAC	$\omega\tau_{250}/\omega\tau_{113}=$ 0.23 6	Lu(pile n) implanted in Fe
								‡For $T_{1/2}=55$ 5ps [73Go47]	
$^{177}_{72}\text{Hf}$	321	660ps	[9/2]	-0.508 17		69Hu10	IPAC		foils; $H_{\text{int}}=-140$ 10kG
									Lu in Fe foil; $H_o=10\text{kG}$ , $H_{\text{hf}}=$ -286 40kG using data of 62Ma42 for $g\tau(113)$
$^{178}_{72}\text{Hf}$	93	1.50ns	[2]	+0.71 7		62Bo13	IPAC	$\omega\tau=182$ 17mr	aqueous $(\text{NH}_4)_2\text{WO}_4$ ; $H_o=49.55\text{kG}$ ( $H_{\text{int}}$ uncertain ~10%, 65Ma27)
$^{178}_{72}\text{Hf}$	93	1.50ns	[2]	+0.58 <sup>d</sup> 4		62Ka14	IPAC	$\omega\tau/H=+3.0$ 2mr/kG	$^{178}\text{W}$ in HF acid; $H_o=25.2$ , 45.7 kG; $G_2=0.74$ 9, $G_4=0.818$ 46 ( $H_{\text{int}}$ uncertain ~10%, 65Ma27)
$^{178}_{72}\text{Hf}$	93	1.50ns	[2]	+0.59 8		67Gi02	IMPAC	$\omega\tau=46.1$ 28mr	CEx with O, recoils in Cu; $H_o=16.6\text{kG}$ ; $X=0.913$ 87
$^{178}_{72}\text{Hf}$	93	1.50ns	[2]	+0.464 28		68Be04	IMPAC	$\omega\tau=41.2$ 18mr	CEx with O, recoils in liquid Ga; $G_2=0.982$ 23, $H_o$ not given
$^{178}_{72}\text{Hf}$	93	1.50ns	[2]			71Gu06	IMPAC	$\omega\sigma(^{178}\text{Hf}+^{180}\text{Hf})$ =0.34 3r at room $T$	CEx with $^4\text{He}$ and $^{16}\text{O}$ on Hf metal crystal

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat — Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{180}_{72}\text{Hf}$	93	1.50ns	[2]	+0.757 65		61Bo25	IPAC	$\omega\tau=166 \pm 13\text{mr}$	liquid $\text{HfF}_4$ in HF; $H_o=42.5\text{kG}$ ( $H_{int}$ uncertain ~10%, 65Ma27)
$^{180}_{72}\text{Hf}$	93	1.50ns	[2]	+0.626 70		67Gi02	IMPAC	$\omega\tau=49.2 \pm 25\text{mr}$	#Paper quotes $\omega\tau=1.66 \pm 13$ (Unit not given) CEx with O, recoils in Cu; $H_o=16.6\text{kG}$ , $X=0.913 \pm 7$
$^{180}_{72}\text{Hf}$	93	1.50ns	[2]	+0.526 30		68Be04	IPAC	$\omega\tau=46.7 \pm 20\text{mr}$	CEx with O, recoils in liquid Ga; $G=0.982 \pm 3$ ; $H_o$ not given
$^{180}_{72}\text{Hf}$	309	71ps	[4]	+2.3 4		61Bo25	IPAC	$\omega\tau=0.91 \pm 6^\circ$	liquid $\text{HfF}_4$ in HF; $H_o=53.2\text{kG}$ ( $H_{int}$ uncertain ~10%, 65Ma27)
$^{181}_{73}\text{Ta}$	482	10.8ns	[5/2]	$\pm 3.34^d 4$	positive	62Bo09	DPAC	$\omega=134.3 \pm 7\text{Mr/s}$	$\text{HfF}_4 + \text{H}_2\text{O}$ ; $H_o=21.15 \pm 20\text{kG}$
$^{181}_{73}\text{Ta}$	482	10.8ns	[5/2]	$\pm 3.34^d 4$		63Be46	‡		$\text{HfOCl}_2 \cdot 8$ ; $(\text{NH}_4)_2\text{HfF}_6$ single crystals
$^{181}_{73}\text{Ta}$	482	10.8ns	[5/2]	+3.23 <sup>d</sup> 5		63Ma10	DPAC	#Observed circular polarization of 482 $\gamma$	$\text{HfO}_2$ (pile n, ), dissolved in 26N HF; $H_o=29.8 \pm 3, 32.05 \pm 32\text{kG}$ ( $H_{int}$ uncertain ~10%, 65Ma27)
$^{181}_{73}\text{Ta}$	482	10.8ns	[5/2]	+3.23 <sup>d</sup> 5		64Ag02	CDPAC		$\text{HfF}_4$ in 27N HF; $H_o \leq 20\text{kG}$
$^{181}_{73}\text{Ta}$	482	10.8ns	[5/2]	+3.03 <sup>d</sup> 18		67Ka26	DPAC	$\omega=114\text{Mr/s}$	$t_{delay}=30.6, 40.0, 41.0\text{ns}$ dilute $\text{HfF}_4$ solution; $H_o=20\text{kG}$
$^{181}_{73}\text{Ta}$	482	10.8ns	[5/2]	$\pm 3.320^p 25$		69Ni14	DPAC		$H_o=22\text{kG}$
$^{181}_{73}\text{Ta}$	482	10.8ns	[5/2]	$\pm 3.30^d 12$		70Li16	DPAC	$\nu_q=52.6 \pm 6\text{MHz}$	Hf single crystal
$^{182}_{73}\text{Ta}$	gs	115d	[3]	$\pm 2.6 \pm 2$		72Kr05	GAP	$\nu=152 \pm 5\text{MHz}$ $B_2=-0.705 \pm 23$ $B_4=0.082 \pm 5$ $\Delta/k=21 \pm 2\text{m}^\circ\text{K}$	$H_{res}=24.2\text{kG}$ $^{182}\text{Ta} + ^{54}\text{Mn}$ in Fe; $H_{hf}=-656$ kG; $T=24 \pm 2\text{m}^\circ\text{K}$
$^{182}_{74}\text{W}$	100	1.37ns	[2]	+0.403 38		62Go17	IPAD		CEx with $^1\text{H}$ on $^{182}\text{W}$ metal; $H_o=20.3 \pm 2\text{kG}$ ; $G_2=0.925 \pm 30$
$^{182}_{74}\text{W}$	100	1.37ns	[2]	$\pm 0.49^a 7$		63Kl04	IPAC	$G_2\omega\tau=2^\circ 5'$	Ta metal; $H_o=35\text{kG}$ ; $G_2=0.82$
$^{182}_{74}\text{W}$	100	1.37ns	[2]	$\pm 0.65^a 10$		63Ko02	DPAC	$\omega\tau=2^\circ 56'$	Ta in $\text{HF}+\text{HNO}_3$ ; $H_o=35\text{kG}$ , $G_2=1$
$^{182}_{74}\text{W}$	100	1.37ns	[2]	+0.67 9		64Sc21	DPAD		liquid TaF in HF; $G_2=1.5 \pm 12$ , $G_4=0.91 \pm 5$
$^{182}_{74}\text{W}$	100	1.37ns	[2]	+0.74 12		65Ch14	IPAD		( $H_{int}$ uncertain ~10%, 65Ma27)
$^{182}_{74}\text{W}$	100	1.37ns	[2]	+0.478 40		72Gr22			CEx with $^1\text{H}$ on $^{182}\text{W}$ metal; $H_o \sim 34\text{kG}$
$^{182}_{74}\text{W}$	100	1.37ns	[2]	+0.466 <sup>d</sup> 54		65Eb03	IPAD	#Coherence effects ignored in analysis	Möss. scattering from W foil using Ta source at 15 $^\circ\text{K}$ ; $H_o=22.5\text{kG}$ , assumed $\beta=1$ , $\omega_B=0$
$^{182}_{74}\text{W}$	100	1.37ns	[2]	+0.498 48		70Be36	AAC	$\omega^2\tau_c=0.0506 \pm 41$ $r^2/\text{ns}$	CEx with $^1\text{H}$ on $^{182}\text{W}$ metal; $H_o \leq 41.6\text{kG}$
$^{182}_{74}\text{W}$	100	1.37ns	[2]	$\pm 0.520 \pm 22$		71Se12	IPAC	$G_4\omega\tau=0.028 \pm 7\text{r}$	CEx with O, recoils in He gas
$^{182}_{74}\text{W}$	100	1.37ns	[2]	+0.38 10		67Bo32	IMPAC	$\omega\tau_{4+}=+32 \pm 13\text{mr}$ $\omega\tau_{2+}=+1.00 \pm 25\text{r}$	powdered Ta metal (pile n, ); $H_o=15.9\text{kG}$
$^{182}_{74}\text{W}$	329	64ps	[4]	+0.64 <sup>p</sup> 28		67Gi03	IMPAC	$\omega\tau=35 \pm 9\text{mr}$	CEx with O on $\text{WO}_3$ , recoils in Fe; used $g_{2+}=0.244$ to obtain $H_{int}=-430 \pm 100\text{kG}$
$^{182}_{74}\text{W}$	329	64ps	[4]	+0.73 24		67Be45		#Assumed pure magnetic interaction	CEx with O, recoils in Fe; assumed $H_{int}=460 \pm 45\text{kG}$ , $X=0.97 \pm 3$ , $G_{ave}=0.87 \pm 4$
				+0.84 <sup>c</sup> 28				Used conical magnetic field calculations to account for anomalous field on recoils	

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat — Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{182}_{74}\text{W}$	1289	1.04ns	[2]	+1.00 24		68Bh02	IPAC	$\omega\tau=-116.26\text{mr}$	$H_o=32.5\text{kG}$
$^{182}_{74}\text{W}$	1289	1.04ns	[2]	$\pm 1.83^p 24$		72Se15	IPAC	$\omega\tau=98.13\text{mr}$	Ta powder(n, ); $H_o=15.9\text{kG}$
$^{182}_{74}\text{W}$	1374	2.25ns	[3]	$\pm 0.096^p 12$		72Se15	IPAC	$\omega\tau=207.26\text{mr}$	Ta-Fe(n, ); $H_{int}=598.13\text{kG}$
$^{183}_{74}\text{W}$	99	700ps	[5/2]	+0.55 28		67Gi03	IMPAC	$\omega\tau=17.4.90\text{mr}$	CEx with O on W, recoils in Cu; $H_o=16.6\text{kG}$ , $X=0.97.3$ , $G_2=0.95.2$ , $G_4=0.97.2$
$^{184}_{74}\text{W}$	111	1.26ns	[2]	$\pm 0.63.8$		64Ko13	IPAC		KReO <sub>4</sub> +H <sub>2</sub> O; $H_o=49.8\text{kG}$ ; $G_2=0.90.20$ , $G_4=0.85.8$
				$\pm 0.557.34$			IPAC		W metal(d,p); $H_o=49.8\text{kG}$ , $G_4 \geq 0.93.5$
$^{184}_{74}\text{W}$	111	1.26ns	[2]	+0.564 36		65Eb03	IPAD		CEx with <sup>1</sup> H on <sup>184</sup> W metal; $H_o \leq 41.6\text{kG}$ , $G_2=0.916.21$
$^{184}_{74}\text{W}$	111	1.26ns	[2]	+0.550 50		65Sc05	DPAD		CEx with <sup>1</sup> H on W metal
$^{184}_{74}\text{W}$	111	1.26ns	[2]	+0.62 <sup>a</sup> 8		67Gi02	IMPAC		CEx with O, recoils in Cu; $X=0.912.88$
$^{184}_{74}\text{W}$	111	1.26ns	[2]			71Ka33	AAC	$Q/Q^{182}(100)=1.0.1$	CEx implantation into Gd single crystal
$^{184}_{74}\text{W}$	364	43.5ps	[4]	+1.20 36		67Gi03	IMPAC	$\omega\tau=40.10\text{mr}$	CEx with O, recoils in Fe; assumed $H_{int}=460.45\text{kG}$ ; $G_2=0.849.25$ , $G_4=0.900.18$
				+1.38 <sup>c</sup> 40		67Be45			Used conical field calculations to account for anomalous magnetic field on recoils
$^{184}_{74}\text{W}$	364	43.5ps	[4]	+1.14 14		70Ge06	IPAC	$\omega\tau=-51.7.30\text{mr}$	W in Fe at 300°K; used $g_{2+}=0.282.9$ and $T_{2+}=1.26\text{ns}$ to get $H_{int}=-610.35\text{kG}$
								$\omega\tau_{2+}=-1461.66\text{mr}$	$g/g_{2+}=1.02.14$
$^{186}_{74}\text{W}$	123	1.01ns	[2]	+0.584 54		62Go17	IPAD		CEx with <sup>1</sup> H on <sup>186</sup> W metal; $H_o=20.3.2\text{kG}$ ; $G_2=0.940.25$
$^{186}_{74}\text{W}$	123	1.01ns	[2]	+0.77 $\ddagger$ 7		65Ch14 72Gr22	IPAD		Möss. scattering from W foil using <sup>186</sup> Re source at 15°K; $H_o=22.5\text{kG}$ , assumed $\beta=1$ , $\omega_E=0$
$^{186}_{74}\text{W}$	123	1.01ns	[2]	+0.56 <sup>a</sup> 12		65Eb03 63Kl02	IPAC	$g_{2+}^{182,184,186}=0.276$	#Coherence effects ignored in analysis
$^{186}_{74}\text{W}$	123	1.01ns	[2]	+0.70 7		67Gi02	IMPAC	$\omega\tau=38.9.23\text{mr}$	CEx with O, recoils in Cu; $H_o=16.6\text{kG}$ , $X=0.94.6$ ; $G_2=0.900.27$ , $G_4=0.947.19$ , $G_{avc}=0.929.10$
$^{186}_{74}\text{W}$	123	1.01ns	[2]	+0.702 60		67Ku07	DPAD		CEx with <sup>1</sup> H on polycrystalline W metal at room T; $H_o=33\text{kG}$
$^{186}_{74}\text{W}$	123	1.01ns	[2]	$\pm 0.644.26$		70Be36	AAC	$\omega^2\tau_E=0.0774.63$ or $0.0463.36^2/\text{ns}$	CEx recoils in He or Ar gas
								$g/g^{182}(100)=1.237.71$	
$^{186}_{74}\text{W}$	123	1.01ns	[2]			71Ka33	AAC	$Q/Q^{182}(100)=1.2.2$	CEx implantation into Gd single crystal
$^{186}_{74}\text{W}$	399	25.4ps	[4]	+0.76 52		67Gi03	IPAD	$\omega\tau=12.5.80\text{mr}$	CEx with O, recoils in Fe; assumed $H_{int}=460.45\text{kG}$ ; $G_2=0.900.27$ , $G_4=0.947.19$
				+0.87 <sup>c</sup> 60		67Be45			Used conical field calculations to account for anomalous magnetic field on recoils

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat – Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{183}_{75}\text{Re}$	gs	70d	[5/2]	$\pm 2.88^p 12$		72Va26	GAP		Re–Fe; $H_{\text{hf}}=-760$ 15kG
$^{183}_{75}\text{Re}$	gs	70d	[5/2]	$\pm 3.19 15$		73Kr01	GAP	$\Delta=\pm 35.5$ 15m°K	Re–Fe; $H_{\text{int}}=760$ 15kG; used $^{54}\text{Mn}$ in Fe as thermometer
$^{183}_{75}\text{Re}$	496	7.89ns	[9/2]	$\pm 5.31 31$		68Ge08	DPAC	$\omega=168$ 10Mr/s	Os electroplated on Cu foil, then melted; $H_o=29.6$ 3kG
$^{184}_{75}\text{Re}$	gs	38d	[3]	$\pm 2.67^p 16$		72Va26	GAP		Re–Fe; $H_{\text{hf}}=-760$ 15kG
$^{184}_{75}\text{Re}$	gs	38d	[3]	$\pm 2.48 12$		73Kr01	GAP	$\Delta=\pm 23$ 1m°K	Re–Fe; $H_{\text{int}}=760$ 15kG; used $^{54}\text{Mn}$ in Fe as thermometer
$^{184}_{75}\text{Re}$	188	165d	[8]	$\pm 2.77^p 14$		72Va26	GAP		Re–Fe; $H_{\text{hf}}=-760$ 15kG
$^{184}_{75}\text{Re}$	188	165d	[8]	$\pm 2.90 15$		73Kr01	GAP	$B_2=1.044$ 38 $B_4=0.311$ 64 $\Delta=\pm 10.1$ 5m°K	Re–Fe; $H_{\text{int}}=760$ 15kG; used $^{54}\text{Mn}$ in Fe as thermometer
$^{187}_{75}\text{Re}$	206	560ns	[9/2]	$\pm 4.71^d 14$		63Ko19	DPAC		$\text{Li}_2\text{WO}_4+\text{H}_2\text{O}$ ; $H_o=1.72, 5.02$ kG ( $H_{\text{int}}$ uncertain ~10%, 65Ma27)
$^{187}_{75}\text{Re}$	206	560ns	[9/2]	+5.02 6		63Wal6	DPAC	No appreciable attenuation, $\Delta\nu_Q<18$ MHz $\omega=16.83$ 11Mr/s‡	saturated $(\text{NH}_4)_2\text{WO}_4+\text{H}_2\text{O}$ ; $H_o=3.15$ 3kG ( $H_{\text{int}}$ uncertain ~10%, 65Ma27)
$^{187}_{75}\text{Re}$	206	560ns	[9/2]	+4.68 <sup>d</sup> 18		71Ni01	DPAC	‡Unit given as MHz $\omega=15.31$ 53Mr/s	$(\text{NH}_4)_2\text{WO}_4$ in aqueous solution; $H_o=3.10$ 3kG measured by proton resonance with Beckman–Hall probe
$^{186}_{76}\text{Os}$	137	840ps	[2]	+0.632 56		61Bo08	IPAC	$\omega\tau=98$ 8mr	$\text{HReO}_4$ aqueous solution; $H_o=53.50$ 15kG ( $H_{\text{int}}$ uncertain ~10%, 65Ma27)
$^{186}_{76}\text{Os}$	137	840ps	[2]	+0.50 13		61Le06	IPAC	$\omega\tau=43$ 10mr	Re metal dissolved in $\text{HNO}_3$ ; $H_o=29.2$ kG
$^{186}_{76}\text{Os}$	137	840ps	[2]	+0.64‡ 3		65Ch14 72Gr22	IPAD		Möss. scattering from $^{186}\text{Os}$ metal powder using $^{186}\text{Re}$ source at 15°K; $H_o=22.5$ kG; assumed $\beta=1$ , $\omega_E=35.6$ Mr/s
$^{186}_{76}\text{Os}$	137	840ps	[2]	+0.548 38		67Gi02	IPAC	‡Coherence effects ignored in analysis $\omega\tau=25.0$ 14mr	CEx with $^{16}\text{O}$ , recoils in Cu; $H_o=16.6$ kG, $X=0.963$ 37
$^{188}_{76}\text{Os}$	155	710ps	[2]	+0.59 7		61Ka09	IPAC	$\omega\tau=42.3$ 34mr	powdered Re metal in dilute $\text{HNO}_3$ ; $H_o=29.2$ kG ( $H_{\text{int}}$ uncertain ~10%, 65Ma27)
$^{188}_{76}\text{Os}$	155	710ps	[2]	+0.41 4		63Go05	IPAD	$\omega\tau=20$ 1mr	CEx with $^1\text{H}$ on Os metal; $H_o=19.8$ 2kG
$^{188}_{76}\text{Os}$	155	710ps	[2]	+0.46 6		64Sp02	IPAD		CEx with $^1\text{H}$ on $^{188}\text{Os}$ metal; $H_o=41.07$ kG, $X=0.91$ 10, $G_2=0.894$ 20
$^{188}_{76}\text{Os}$	155	710ps	[2]	+0.61‡ 5		64Sp09	AAC	$\Delta\nu_Q=278$ 32MHz $Q/Q_{2+}^{19.0}=1.11^{+28}_{-19}$	CEx with $^1\text{H}$ on Os powder
$^{188}_{76}\text{Os}$	155	710ps	[2]	+0.540 36		65Ch14 72Gr22	IPAD		Möss. scattering from Os metal powder using $^{188}\text{Re}$ source at 15°K; $H_o=22.5$ kG, assumed $\beta=1$ , $\omega_E=0.034$ 4
$^{188}_{76}\text{Os}$	155	710ps	[2]	+0.560 <sup>e</sup> 42		66Go06	IMPAC	‡Coherence effects ignored in analysis $\omega\tau=21.9$ 12mr	CEx with O on $^{188}\text{Os}$ , recoils in Cu; $H_o\sim 17$ kG, $G_2=0.956$ , $G_4=0.917$
						67Gi02		Recalculated using $X=0.964$ 36, $H_o=16.6$ kG	

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat — Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{188}_{76}\text{Os}$	155	710ps	[2]	$\pm 0.570\ 24$		70Be36	AAC	$\omega^2\tau_e=0.078\ 6$ or $0.046\ 4\tau^2/\text{ns}$	CEx recoils in He or Ar gas
$^{188}_{76}\text{Os}$	155	710ps	[2]	$\pm 0.512^{+0.52}$		71Si33	IMPAC		CEx recoils in Fe; compared with $g^{188}(633); H\tau_i=$ $17.9\text{MG-ps}$
$^{188}_{76}\text{Os}$	633	5.6ps	[2]	$+1.16\ 36$		67Ke01	IPAC		Fe-Re(pile n, ); $H_{\text{int}}=1.4\text{MG}$ ; corrected for $(1308\gamma)(633\gamma)$
$^{188}_{76}\text{Os}$	633	5.6ps	[2]	$+0.86\ 16$		67Mu05	IPAC		Re in Fe; $H_{\text{int}}=1.145\ 25\text{MG}$
$^{190}_{76}\text{Os}$	187	350ps	[2]			64Sp09	AAC	$Q/Q^{192}(206)=$ $1.03\ 30$	CEx with $^1\text{H}$ on Os powder
$^{190}_{76}\text{Os}$	187	350ps	[2]	$+0.74\ 10$		66Go06	IMPAC	$\omega\tau=14.8\ 13\text{mr}$	CEx with O on $^{190}\text{Os}$ , recoils in Cu; $H_o \sim 17\text{kG}$ ; $G_2=0.956$ , $G_4=0.917$
$^{190}_{76}\text{Os}$	187	350ps	[2]	$+0.75^{\circ}\ 10$		67Gi02		Recalculated using $X=0.978\ 23$ , $H_o=16.6\text{kG}$	
$^{190}_{76}\text{Os}$	187	350ps	[2]	$\pm 0.662\ 32$		70Be36	AAC	$\omega^2\tau_e=0.062\ 6\tau^2/\text{ns}$ $g/g^{188}(155)=1.162\ 76$	CEx recoils in Ar gas
$^{190}_{76}\text{Os}$	187	350ps	[2]	$+0.37\pm 4$		70Le04	IPAC	$\omega\tau=650\ 5\text{mr}$	$^{190}\text{Ir-Os}$ in Fe; $H_{\text{int}}=-1.43\text{MG}$
$^{190}_{76}\text{Os}$	548	28ps	[4]	$+0.88\pm 48$		70Le04	IPAC	$\omega\tau=60\ 14\text{mr}$	$\dagger$ Value of $H_{\text{int}}$ may be uncertain, 71Ki13
$^{192}_{76}\text{Os}$	206	280ps	[2]	$+0.77\ 11$		66Go06	IMPAC	$\omega\tau=12.4\ 11\text{mr}$	$^{190}\text{Ir-Os}$ in Fe; $H_{\text{int}}=-1.43\text{MG}$
$^{192}_{76}\text{Os}$	206	280ps	[2]	$+0.79^{\circ}\ 10$		67Gi02		Recalculated using $X=0.979\ 21$ ; $H_o=16.6\text{kG}$	
$^{192}_{76}\text{Os}$	206	280ps	[2]			71Av06	AAC	$Q/Q_{2+}^{190}=0.97\pm 15$	CEx implantation into fused quartz
$^{192}_{76}\text{Os}$	206	280ps	[2]	$+0.815\ 37$		71Ki13	IPAC	$\omega\tau_{\text{ave}}=223\ 5\text{mr}$	$\ddagger$ Assumed only quadrupole interactions
$^{192}_{76}\text{Os}$	206	280ps	[2]						$\text{Ni-Ir(pile n, ); } H_{\text{int}}=$ $282.3\ 10\text{kG}$
$^{192}_{76}\text{Os}$	206	280ps	[2]						Great variation in $\omega\tau$ and $A_2$ in Fe-Ir samples casts doubt on earlier measurements in Fe hosts
$^{192}_{76}\text{Os}$	206	280ps	[2]	$\pm 0.754^{+0.48}$		71Si32	IMPAC	$\omega\tau=197\ 8\text{mr}$	CEx with $^{16}\text{O}$ on Os metal on polarized Ni; used $H\tau_i=$ $4.57\ 88\text{MG-ps}$
$^{192}_{76}\text{Os}$	489	28ps	[2]	$\pm 0.66^{\circ}\approx 21$		71Si25	IMPAC	$g/g^{192}(206)=$ $0.86^{\pm} 22$	CEx on Os on Fe; $H\tau_i=$ $17.9\ 51\text{MG-ps}$
									$\ddagger$ Used $\mu(206)=0.77\ 11$
$^{191}_{77}\text{Ir}$	129	131ps	[5/2]	$\pm 3.00\ 58$		68Da19	IPAD		Möss. scattered $\gamma$ 's from Ir; $H_o=24.5\text{kG}$
$^{191}_{77}\text{Ir}$	129	131ps	[5/2]	$+0.42\ 5$		69Ow02	IPAC	$\omega\tau=229\ 13\text{mr}$	$^{191}\text{Pt}$ in Fe; $H_{\text{int}}=1.510\ 52\text{MG}$
$^{191}_{77}\text{Ir}$	129	131ps	[5/2]	$\pm 0.56\ 10$		70Av02	AAC	$\omega^2\tau_e=0.034\ 7\tau^2/\text{ns}$ $g/g_{5/2}^{193}=0.79\ 12$	CEx on $\text{H}_2\text{IrCl}_6$ , recoils in Ar
$^{192}_{77}\text{Ir}$	171	4.9s	[11/2]	$\pm 6.3^{\circ}\ 15$		64Ca11	GAP	$\mu H=43\ 3\text{a-ergs}$	$^{191}\text{Os}$ and $^{60}\text{Co}$ in Fe; $H_{\text{int}}=$ $135\ 30\text{MG}$
$^{191}_{77}\text{Ir}$	171	4.9s	[11/2]	$\pm 6.03\ 36$		71Es03	GAP— NMR	$\nu=389.690\pm 13$ , $1174.85\pm 12\text{MHz}$	Observed $0.129\gamma(\theta, T)$ $0.08\% \ ^{191}\text{Os-Ni}; H_{\text{int}}=-467\ 3\text{kG}$
$^{192}_{77}\text{Ir}$	gs	74d	(4)	$\pm 1.8^{+6}_{-5}$		63Ko21	GAP SpHt	$\ddagger$ Extrapolated to $H_o=0$ $\mu H=12^{+2}_{-1}\ 3\text{a-ergs}$	$0.04\% \ ^{191}\text{Os-Fe}; H_{\text{int}}=-1405\ 8$ kG
$^{192}_{77}\text{Ir}$	gs	74d	(4)	$\pm 1.8\ 2$		64Ca15	GAP	$\mu H=13.5\ 3\text{a-ergs}$ $\mu H(^{191,193}\text{Ir})=$ $1.14\ 9\text{a-ergs}$	Ir in Fe; $^{60}\text{Co}$ in Fe used to measure $T\sim 0.1$ to $0.012^\circ\text{K}$ ; used $\mu^{191,193}=0.15\ 1$

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat — Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{192}\text{Ir}_{77}$	gs	74d	(4)	$\pm 1.41\ 8$		69Re06		$\mu H=10.8\ \text{3a-ergs}$	$^{192}\text{Ir}$ in Fe; $^{60}\text{Co}+^{192}\text{Ir}$ in Fe; $T\sim 0.013^\circ\text{K}$ ; assumed $H_{\text{eff}}=-1.52\ 3\text{MG}$
$^{192}\text{Ir}_{77}$	gs	74d	(4)	positive		70Hi12	BAP GAP	$\mu H=13\text{a-ergs}$	$^{192}\text{Ir}$ in Fe; $H_{\text{eff}}$ negative
$^{192}\text{Ir}_{77}$	gs	74d	(4)	$\pm 1.901^d\ 11$		71Es03	GAP— NMR	$\nu=167.661\pm 35,$ $504.192\pm 50\text{MHz}$	0.03% $^{192}\text{Ir-Ni}$ ; $H_{\text{int}}=-467\ 3\text{kG}$ $^{192}\text{Ir-Fe}$ ; $H_{\text{int}}=-1405\ 8\text{kG}$
$^{193}\text{Ir}_{77}$	139	90ps	[5/2]	$+0.46\ 8$		67Gu10	IPAC	$\omega\tau=6.0\ 7\text{mr}$	$^{193}\text{OsO}_4$ dissolved in aqua regia and $\text{H}_2\text{O}$ ; $H_o=52.0\ 5\text{kG}$
$^{193}\text{Ir}_{77}$	139	90ps	[5/2]	$\pm 0.71\ 12$		70Av02	AAC	$\omega^2\tau_c=0.055\ 10\text{r}^2/\text{ns}$	CEx recoils in Ar gas
$^{194}\text{Ir}_{77}$	gs	17h	(1)	$\pm 0.37\ 4$		69Re06	GAP	$\mu H=2.8\ \text{3a-ergs}$	1% Ir in Fe; $H_{\text{int}}=-1.52\ 3\text{MG}$ ; assumed no hyperfine anomaly
$^{192}\text{Pt}_{78}$	316	35ps	[2]	$+0.51\ 8$		66Ag02	IPAC	$\omega\tau=80\ 5\text{mr}$	dilute Ir-Fe; $H_{\text{int}}=1.32\ 8\text{MG}$
$^{192}\text{Pt}_{78}$	316	35ps	[2]	$\pm 0.60\ 6$		69Ke11	IPAC	$\omega\tau=88\ 5\text{mr}$	1% Ir in Fe; $H_{\text{int}}=1.25\ 3\text{MG}$ ; $G_2=0.94$ , $G_4=0.80$
$^{192}\text{Pt}_{78}$	316	35ps	[2]	$+0.584\ 44$		70Be08	IPAC	$\omega\tau=87.5\ 24\text{mr}$	Ir-Fe; $H_{\text{int}}=-1.235\ 20\text{MG}$
$^{192}\text{Pt}_{78}$	316	35ps	[2]	$+0.54\ 4$		70Gr25	IPAC	$\omega\tau=80\ 2\text{mr}$	Pt implanted in Ir-Fe; $H_{\text{int}}=-1.24\ 3\text{MG}$
$^{192}\text{Pt}_{78}$	316	35ps	[2]	$+0.56\ 6$		70Le04	IPAC	$\omega\tau=88\ 6\text{mr}$	Ir melted into Fe; $H_{\text{int}}=-1.235\text{MG}$
$^{192}\text{Pt}_{78}$	316	35ps	[2]	$+0.92\ 11$		71Ki13	IPAC	$\omega\tau=36\ 4\text{mr}$	(Ni-Ir)(pile n, ); $H_{\text{int}}=323\ 10\text{kG}$
$^{192}\text{Pt}_{78}$	316	34.6ps	[2]	$+0.550^{\text{ep}}\ 32$		72Ro30	IPAC		Fe-Ir alloys not suitable for PAC
$^{192}\text{Pt}_{78}$	612	20ps	[2]	$\pm 0.86\pm 21$		69Ke11	IPAC	$\omega\tau=47\pm 11\text{mr}$	1% Ir in Fe; $H_{\text{int}}=1.25\ 3\text{MG}$
									‡From $\omega\tau$ -ratio and $\mu(316)=+0.92$
									†Corrected for $(604\gamma)(316\gamma)$
$^{192}\text{Pt}_{78}$	612	20ps	[2]	$+0.98\pm 17$		70Be08	IPAC	$\omega\tau=53\ 9\text{mr}$	Ir-Fe; $H_{\text{int}}=1.235\ 20\text{MG}$
$^{192}\text{Pt}_{78}$	612	20ps	[2]	$+1.13\pm 20^{\text{ep}}$		70Gr25	IPAC	$\omega\tau=56\pm 6\text{mr}$	‡From $\omega\tau$ -ratio and $\mu(316)=+0.92$
									Pt implanted in Ir-Fe; $H_o\sim 2\text{kG}$
									$H_{\text{int}}=-1.24\ 3\text{MG}$
									‡From $\omega\tau$ -ratio and $\mu(316)=+0.92$
									†Corrected for $(604\gamma)(316\gamma)$
$^{192}\text{Pt}_{78}$	612	20ps	[2]	$+0.99\pm 20$		70Le04	IPAC	$\omega\tau=54\ 11\text{mr}$	$^{192}\text{Ir}$ in Fe, melted; $H_{\text{int}}=-1.235\text{MG}$
									‡From $\omega\tau$ -ratio and $\mu(316)=+0.92$
$^{192}\text{Pt}_{78}$	612	20ps	[2]	$+0.62^{\text{ep}}\ 9$		72Ro30	IPAC		
				$+1.04\pm 10$					‡From $\omega\tau$ -ratio and $\mu(316)=+0.92$
$^{192}\text{Pt}_{78}$	785	12ps	[4]	$\pm 0.86\pm 60$		69Ke11	IPAC	$\omega\tau=14\ 10\text{mr}$	1% Ir in Fe; $H_{\text{int}}=1.25\ 3\text{MG}$
$^{194}\text{Pt}_{78}$	328	35ps	[2]	$\pm 0.54\ 8$		65Ke11	IPAC	$\omega\tau=91.6\pm 67\text{mr}$	‡From $\omega\tau$ -ratio and $\mu(316)=+0.92$
				$\pm 0.61\pm 9$					‡For $H_{\text{int}}=1.25\text{MG}$
$^{194}\text{Pt}_{78}$	328	35ps	[2]	$+0.79\pm 36^{\text{ep}}$		65Sp03	IPAC	$\omega\tau=3.92\text{mr}$	‡Corrected for other cascades
$^{194}\text{Pt}_{78}$	328	35ps	[2]	$+0.62\ 8$		66Ag02	IPAC	$\omega\tau=99\pm 9\text{mr}$	CEx with $^1\text{H}$ on $^{194}\text{Pt}$ metal; $H_o=41.6\text{kG}$
				$+0.66\pm 9$					Dilute Pt-Fe; $H_{\text{int}}=1.32\ 8\text{MG}$
$^{194}\text{Pt}_{78}$	328	35ps	[2]	$+0.64\ 8$		67Ka16	IMPAC	$\omega\tau=70\ 5\text{mr}$ , corrected for	‡Corrected for other cascades
				$+0.54^{\text{ep}}\pm 12$		69Ku06			CEx with O, $^{194}\text{Pt}$ recoils in polarized Fe; $H_{\text{int}}=-890\ 70\text{kG}$
									‡Used data on $\omega\tau$ and $\tau$ to correct for transient fields. Used $H_{\text{eff}}=17.7\ 34\text{MG-ps}$ and $H_{\text{int}}=-1.21\ 5\text{MG}$

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat – Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{194}_{78}\text{Pt}$	328	35ps	[2]	$\pm 0.57\ 8$ $\pm 0.59 \pm 6$		70Ke14	IPAC	$\omega\tau=87\ 4\text{mr}$ $\omega\tau=89 \pm 3\text{mr}$	Ir–Fe; $H_{\text{int}}=1.25\ 5\text{MG}$
$^{194}_{78}\text{Pt}$	328	35ps	[2]			70Ke18	IMPAC	$\omega\tau=77\ 5\text{mr}$ †Weighted average of 70Ke14, 66Ag02, 65Kell	CEx with $2.5\text{MeV}^1\text{H}$
$^{194}_{78}\text{Pt}$	328	35ps	[2]	$+0.596^{\text{cp}}\ 36$		72Ro30	IPAC	$\omega\tau=78\ 13\text{mr}$	If transient fields responsible for precession, $H\tau_i \sim +11.6\ 43\text{MG-ps}$
$^{194}_{78}\text{Pt}$	622	44ps	[2]	$\pm 0.36\ 10$ $\pm 0.41 \pm 11$		65Kell	IPAC	$\omega\tau=78\ 13\text{mr}$ †For $H_{\text{int}}=1.25\text{MG}$	Ir–Fe; $H_{\text{int}}=1.42\ 11\text{MG}$
$^{194}_{78}\text{Pt}$	622	44ps	[2]	$+0.42\ 14$ $+0.44 \pm 14$		66Ag02	IPAC	$\omega\tau=83\ 20\text{mr}$ †For $H_{\text{int}}=1.25\text{MG}$	Dilute Pt–Fe; $H_{\text{int}}=1.32\ 8\text{MG}$
$^{194}_{78}\text{Pt}$	622	44ps	[2]	$\pm 0.48\ 12$ $\pm 0.44 \pm 8$		70Ke14	IPAC	$\omega\tau=91\ 15\text{mr}$ $\omega\tau=84 \pm 9\text{mr}$	annealed Ir–Fe; $H_{\text{int}}=1.25\ 5\text{MG}$
$^{194}_{78}\text{Pt}$	622	35±ps	[2]	$+0.56^{\text{cp}}\ 9$		72Ro30	IPAC	‡Weighted average (70Ke14, 66Ag02, 65Kell)	
$^{195}_{78}\text{Pt}$	210	67ps	[3/2]	$+0.24\ 9$		69Ku06	IMPAC	$\omega\tau=80\ 24\text{mr}$	CEx with $^{16}\text{O}$ ; $^{195}\text{Pt}$ recoils in Fe; $H_o=1.4\text{kG}$ ; assumed $H_{\text{int}}=-1.21\ 5\text{MG}$ and $H\tau_i=17.7\ 34\text{MG-ps}$
$^{195}_{78}\text{Pt}$	210	67ps	[3/2]	$+0.33\ 9$		69Va05	IPAC	$\omega\tau=108\ 25\text{mr}$	CEx with $^1\text{H}$ on Fe–Pt; $H_{\text{int}}=980\ 80\text{kG}$ measured with $^{194}\text{Pt}$ assumed $g^{194}(328)=+0.32\ 4$
$^{195}_{78}\text{Pt}$	240	230ps	[5/2]	$+0.18\ 5$		69Ku06	IMPAC	$\omega\tau=135\ 27\text{mr}$ or $\omega\tau=124\ 48\text{mr}$	CEx with $^{16}\text{O}$ , recoils in Fe; observed ( $^{16}\text{O}'(240\gamma)$ or ( $^{16}\text{O}'(140\gamma)$ ); assumed $H_{\text{int}}=-1.21\ 5\text{MG}$ and $H\tau_i=17.7\ 34\text{MG-ps}$
$^{195}_{78}\text{Pt}$	240	230ps	[5/2]	$+0.26\ 6$		69Va05	IPAC	$\omega\tau=160\ 22\text{mr}$	CEx with $^1\text{H}$ on Fe–Pt; assumed no transient fields; $H_{\text{int}}=980\ 80\text{kG}$ measured with $^{194}\text{Pt}$ , assumed $g^{194}(328)=+0.32\ 4$
$^{195}_{78}\text{Pt}$	259	4.1d	[13/2]	$\pm 0.597 \pm 15$		72Ba22	GAP–NMR	$\nu=89.5\ 5\text{MHz}$ ‡Uncorrected for hyperfine anomaly	Pt– $^{60}\text{Co}$ –Fe; $H_{hf}=-1280\ 26\text{kG}$
$^{196}_{78}\text{Pt}$	356	35ps	[2]	$+0.50\ 8$		67Ka16	IMPAC	$\omega\tau_{\text{ave}}=55 \pm 3\text{mr}$	CEx with O, $^{196}\text{Pt}$ recoils in polarized Fe; $H_{\text{int}}=-890\ 70\text{kG}$
$^{196}_{78}\text{Pt}$	356	35ps	[2]	$+0.54\ 7$		68Be61	IPAC	‡Corrected for $^{194}\text{Pt}$ $\gamma$ 's	Au in Fe–Pt; $H_{\text{int}}=-1.235\ 5\text{MG}$
$^{196}_{78}\text{Pt}$	356	35ps	[2]	$+0.56\ 7$		68Mu02	IPAC	$\omega\tau=4.97\ 40^\circ$ $\omega\tau=4.74\ 44^\circ$ $\omega\tau_{\text{ave}}=85.0\ 52\text{mr}$	Au implanted in Fe foils
$^{196}_{78}\text{Pt}$	356	35ps	[2]	$+0.52 \pm 22$		69Ku06	IMPAC	‡Used data on $\omega\tau$ and $\tau$ to correct for transient fields; used $H\tau_i=17.7\ 34\text{MG-ps}$ and $H_{\text{int}}=-1.21\ 5\text{MG}$	Au diffused into Fe; $H_{\text{int}}=1.25\ 3\text{MG}$
$^{196}_{78}\text{Pt}$	356	35ps	[2]	$+0.556^{\text{cp}}\ 35$		72Ro30	IPAC		CEx with O, $^{196}\text{Pt}$ recoils in polarized Fe; $H_{\text{int}}=-890\ 70\text{kG}$
$^{198}_{78}\text{Pt}$	408	19ps	[2]	$+0.52\ 8$		67Ka16	IMPAC	$\omega\tau_{\text{ave}}=30.5\ 20\text{mr}$	
$^{195}_{79}\text{Au}$	gs	192d	(3/2)	$\pm 0.13\ 4$		65Ca12	GAP		Au+ $^{60}\text{Co}$ in Fe; $H_{\text{int}}=1.32\ 5\text{MG}$ based on $\mu^{198}=0.590$ and $\mu^{199}=0.270$
$^{196}_{79}\text{Au}$	596	9.7h	(12)	$\pm 5.35 \pm 20$		71Ba94 72Ba86	GAP	$ \mu H _{\text{ave}}=30.6\ 12$ or $6.4\ 4\text{-erg}$	$^{196}\text{Au}+^{60}\text{Co}$ in Fe or Ni; $H_o \sim 4\text{kG}$
								‡Includes hyperfine anomaly correction	

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat — Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{198}_{79}\text{Au}$	367	123ns	[3]	$\pm 3.60^p 24$		70K113	DPAC		
$^{198}_{79}\text{Au}$	?	49h	[12?]	$\pm 5.55^{dp} 34$		72Ba86	GAO		2.5% hyperfine anomaly included
$^{200}_{79}\text{Au}$	?	18.7h	[12]	$\pm 6.10^{dp} 10$		72Ba86	GAO—NMR		2.5% hyperfine anomaly included
$^{183}_{80}\text{Hg}$	gs	8.8s	1/2	$+0.518^d 9$		72Bo09	BAO—NMR		on-line mass separator
$^{185}_{80}\text{Hg}$	gs	50s	1/2	$+0.504^d 4$		72Bo09	BAO—OP		on-line mass separator
$^{187}_{80}\text{Hg}$	gs	2.4m	3/2	$-0.586^{dp} 6$	$-0.3^p 11$	72Ot03 71Bo31	BAO—OP		on-line mass separator
$^{197}_{80}\text{Hg}$	134	7.3ns	[5/2]	$+0.950 65$		70Ge01	DPAC		Cu—Hg amalgam; $H_o=29.5$ 3kG, 33.2 2kG
$^{198}_{80}\text{Hg}$	412	22.0ps	[2]	$+0.76 22$		64Ke02	IPAC	$\omega\tau=81$ 16mr	Fe—Au; $H_{int}=1.42$ MG
$^{198}_{80}\text{Hg}$	412	22.0ps	[2]	$+1.10^p 22$		64Ko15	IPAC		$^{198}\text{Au}$ —metal; $H_o=57.15$ kG
$^{198}_{80}\text{Hg}$	412	22.0ps	[2]			70Ka09	IMPAC	$\Delta\theta=24.5$ 22mr	CEx with O on $^{198}\text{Hg}$ , recoils in polarized Fe; $H_o=1.4$ kG; $H\tau=5.9$ 23MG, used $\omega\tau=40$ 4 mr of Murray to get transient fields
$^{199}_{80}\text{Hg}$	158	2.32ns	[5/2]		$+0.7^{+4}_-2$	56Po14	AAC	$eqQ=1100^{+650}_{-230}$ MHz or $593^{+150}_{-100}$ MHz	Compared anisotropy in liquid metal with powdered $\text{HgCl}_2$ or frozen metal; used $Q^{201}=0.45$ and $eqQ^{201}(\text{HgCl}_2)=720$ MHz, $eqQ^{201}$ (liquid metal) = 708 MHz
$^{199}_{80}\text{Hg}$	158	2.32ns	[5/2]	$+1.03^d 8$		61Gr29	PAC		$\text{Au}(\alpha, 2n)$ ; $H_o=26000$ 75G
$^{199}_{80}\text{Hg}$	533	44m	13/2		$+2.0^p 13$	72Ot03	GAO—OP		on-line mass separator
$^{200}_{80}\text{Hg}$	368	42ps	[2]	$+0.86 22$		70Ka09	IMPAC	$\Delta\theta=47.8$ 24mr $g/g_{2+}^{198}=0.79$ 12	CEx with O on $^{200}\text{Hg}$ , recoils in polarized Fe (See $^{198}\text{Hg}$ —70Ka09); used $g_{2+}^{198}=0.55$ 11
$^{202}_{80}\text{Hg}$	439	26μs	[2]	$+1.18 30$		70Ka09	IMPAC	$\Delta\theta=33$ 3mr $g/g_{2+}^{198}=1.07$ 17	CEx with O on $^{202}\text{Hg}$ , recoils in polarized Fe (See $^{198}\text{Hg}$ —70Ka09); used $g_{2+}^{198}=0.55$ 11
$^{204}_{80}\text{Hg}$	437	46ps	[2]	$+0.80 20$		70Ka09	IMPAC	$\Delta\theta=50$ 3mr $g/g_{2+}^{198}=0.73$ 12	CEx with O on $^{204}\text{Hg}$ , recoils in polarized Fe (See $^{198}\text{Hg}$ —70Ka09); used $g_{2+}^{198}=0.55$ 11
$^{205}_{80}\text{Hg}$	gs	5.5m	1/2	$+0.5911^p 5$		72Ot03	BAO—OP		on-line mass separator
$^{202}_{81}\text{Tl}$	950	560μs	[7]	$\pm 0.896^p 42$		72Ha67	DPAD	$\omega=48.6$ 10kr/s	liquid Hg(pulsed p, ); maximum $H_o=80$ 3G
$^{203}_{81}\text{Tl}$	279	280ps	[3/2]	$+0.16 5$		65Ka02	IPAC	$\omega\tau=10.7$ 27mr	$\text{PbCl}_2$ in 6N HCl; $H_o=50.6$ kG
$^{204}_{82}\text{Pb}$	1274	260ns	[4]	$+0.22 2$		55Kr06	CDPAC		Tl in $\text{HNO}_3$ ; $T_{delay}=352$ ns, Tl in $\text{H}_2\text{SO}_4$ ; $T_{delay}=237$ ns
$^{204}_{82}\text{Pb}$	1274	260ns	[4]	$+0.226 8$		63Sa19	DPAC	$\nu=8.609$ MHz	Bi in $\text{HNO}_3$ ; $H_o=31.81$ kG
$^{204}_{82}\text{Pb}$	1274	260ns	[4]	$+0.220 12$		67Li12	DPAC	$\nu=9.27$ 5MHz	liquid sources; $H_o=35.2$ kG, $G_2=0.978$ 33
$^{204}_{82}\text{Pb}$	1274	260ns	[4]		$\sim \pm 0.3$	71Bo65 (67Li12)	AAC	$\nu_o=2.23$ MHz	Pb in polycrystalline Tl; assumed $\gamma_o(\text{Pb}^{4+}) \sim -50.88$
$^{205}_{82}\text{Pb}$	1014	5.55ns	[13/2]	$-0.975 40$		71Ma59	DPAD		liquid $^{204}\text{Hg}$ (pulsed $\alpha$ , 3n); diamagnetic correction $\approx -$ Knight shift ( $\sim 1.7\%$ )

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat – Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{206}_{82}\text{Pb}$	803	6ps	[2]	-0.02 14		70Za03	IPAC	$\omega\tau=+0.4$ 23mr	Pb in Fe; $H_{\text{int}}=660$ 45kG
$^{206}_{82}\text{Pb}$	2200	123μs	[7]	-0.57 <sup>p</sup> ‡ 5 or -0.35 <sup>p</sup> ‡		69Qu04	AAC	‡If $\tau_{\text{relax}}<\tau$ or $>200\mu\text{s}$	
$^{206}_{82}\text{Pb}$	2200	123μs	[7]	-0.1519 28		72Ma24	DPAD Strob		liquid $^{204}\text{Hg}$ (pulsed $\alpha$ ,2n); diamagnetic correction $\approx$ –Knight shift ( $\sim 1.7\%$ )
$^{206}_{82}\text{Pb}$	2385	29ps	[6]	+0.78 42		70Za03	IPAC	$\omega\tau=-16.7$ 90mr	Pb in Fe; $H_{\text{int}}=660$ 45kG
$^{206}_{82}\text{Pb}$	4027	200ns	[12]	-1.860 <sup>p</sup> 48		72Na16	DPAD		liquid Hg(pulsed $\alpha$ , )
$^{207}_{82}\text{Pb}$	570	129ps	[5/2]	+0.72 10		64Gu03	IPAC	$\omega\tau=+13.0$ 13mr	liquid $\text{BiCl}_3$ ; $H_o=50.6\text{kG}$
$^{207}_{82}\text{Pb}$	570	129ps	[5/2]	+0.96 22		65He10	IPAC	$\omega\tau=3.4$ 21mr	liquid source; $H_o=10\text{kG}$
$^{207}_{82}\text{Pb}$	570	129ps	[5/2]	+0.65 5		66Ko16	IPAC	$\omega\tau=12.9$ 9mr	liquid $^{207}\text{BiCl}_3$ in HCl; $H_o=55.2\text{kG}$
$^{207}_{82}\text{Pb}$	570	129ps	[5/2]	$\pm 0.79^p$ 3		72Sc36	IPAC	$\omega\tau=26.6$ 9mr	$H_o=94.4$ 5kG
$^{208}_{82}\text{Pb}$	2615	15ps	[3]	+1.74 42		69Bo12	IPAC	$\omega\tau=1.80$ 45mr	$^{228}\text{Th}$ in HCl; $H_o \sim 30.5\text{kG}$
$^{208}_{82}\text{Pb}$	2615	15ps	[3]	$\pm 1.89^p$ 29		72Sc36	IPAC	$\omega\tau=5.97$ 79mr	$H_o=94.4$ 5kG
$^{208}_{82}\text{Pb}$	3198	298ps	[5]	+0.105 35		69Bo01	IPAC	$\omega\tau(2615)/\omega\tau(3198)$ =1.36 21	$^{228}\text{Th}$ in Fe, Co; used $g(2615)=+0.58$ 14
$^{207}_{83}\text{Bi}$	2102	182μs	[21/2]	+3.41 6		72Ma24	DPAD Strob		liquid Hg( $^7\text{Li},4\text{n}$ ); diamag- netic correction $\sim$ –Knight shift ( $\sim 1.7\%$ )
$^{210}_{83}\text{Bi}$	gs	5.0d	(1)	negative <sup>p</sup>	positive <sup>p</sup>	72Na17	BAP	observed positive asymmetry	ferromagnetic BiMn; $H_{\text{hf}} \sim 1\text{MG}$ ; used $\mu/Q < 0$ from atomic beams
$^{211}_{83}\text{Bi}$	405	318ps	[7/2]	+4.41 67		65Ag03	IPAC		liquid sources $^{211}\text{Pb}$ or $^{223}\text{Ra} + ^{211}\text{Pb}$ ; $H_o=18.3\text{kG}$
$^{204}_{84}\text{Po}$	~1700	190ns‡	[8]	$\pm 8.32^p$ 64		72Br42	DPAD	‡quoted value	$^{204}\text{Pb}$ foil (pulsed $\alpha$ , )
$^{204}_{84}\text{Po}$	~1700	140ns‡	[8]	$\pm 7.24^p$ 32		72Na18	Strob	‡quoted value	$^{204}\text{Pb}$ foil (pulsed $\alpha$ , ); $H_o=15.9\text{kG}$
$^{206}_{84}\text{Po}$	?	160ns‡	[8]	$\pm 7.60^p$ 32		72Br42	DPAD	‡quoted value	$^{206}\text{Pb}$ (pulsed $^3\text{He}$ , )
$^{206}_{84}\text{Po}$	?	212ns‡	[8]	$\pm 7.24^p$ 32		72Na18	Strob	‡quoted value	liquid $^{206}\text{Pb}$ (pulsed $\alpha$ , )
$^{207}_{84}\text{Po}$	1115	47μs	[13/2]	-0.930 <sup>dkp</sup> 13		72Fo19	DPAD		$^{206}\text{Pb}(\alpha,2\text{n})$ ; $T_o=123.43\text{ns}$
$^{208}_{84}\text{Po}$	>1520	380ns	[8]	$\pm 7.22$ 5 $\pm 7.48$ 40		70Na11	Strob DPAD	$H_o=11.62$ 8kG $\omega=63.2$ 34Mr/s‡	$^{208}\text{Pb}(^3\text{He},3\text{n})$ ; $H_o=13.9\text{kG}$ ; assumed Knight shift $\sim 1.47\%$
$^{208}_{84}\text{Po}$	1532	380ns	[8]	$\pm 7.29^p$ 8		72Na18	Strob	‡Unit given as MHz	$^{208}\text{Pb}(\text{pulsed } ^3\text{He}, )$
$^{209}_{84}\text{Po}$	>1327	~100ns	[17/2??]	+7.48 43 +7.37 <sup>e</sup> 43		68Ya08	DPAD	$\omega=11.6$ 7Mr/s‡	metallic Pb(pulsed $\alpha, \text{xn}$ ); $H_o=2.760\text{kG}$ ; recalculation in- cludes Knight shift $\sim 1.4\%$
$^{209}_{84}\text{Po}$	?	100ns	[17/2]	$\pm 7.62^p$ 13		72Na18	Strob	‡Unit given as MHz	$^{207}\text{Pb}$ (pulsed $\alpha$ , )
$^{210}_{84}\text{Po}$	1472	38ns	[6]	$\pm 5.58^{\text{dkp}}$ 12		72Ba87	DPAD		$^{208}\text{Pb}$ (pulsed $\alpha$ , ); $H_o=13.76$ 7kG
$^{210}_{84}\text{Po}$	1552	110ns	[8]	+7.29 8		70Ya02	DPAD	$\omega=48.44$ 4Mr/s‡	metallic $^{208}\text{Pb}$ (pulsed $\alpha, 2\text{n}$ ); $H_o=10.93\text{kG}$ ; assumed Knight shift $\sim 1.47\%$
$^{210}_{84}\text{Po}$	1552	110ns	[8]	$\pm 7.27^{\text{dkp}}$ 12		72Ba87	DPAD	‡Unit given as MHz	$^{208}\text{Pb}$ (pulsed $\alpha$ , ); $H_o=13.76$ 7kG
$^{210}_{84}\text{Po}$	1552	110ns	[8]	$\pm 7.21^p$ 10		72Na18	Strob		$^{208}\text{Pb}$ (pulsed $\alpha$ , )
$^{210}_{84}\text{Po}$	2800	24ns	[11]	+11.99 18		70Ya06	DPAD	$\omega=101.0$ 15Mr/s‡	metallic $^{208}\text{Pb}$ (pulsed $\alpha, 2\text{n}$ ); $H_o=19.05\text{kG}$ ; assumed Knight shift $\sim 1.47\%$
								‡Unit given as MHz	

**Table J: Nuclear Moments by  
Perturbed Angular Correlation, Aligned Nuclei, and Specific Heat – Continued**

Nucleus	Level	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment & Comments
$^{210}_{84}\text{Po}$	4372	93ns	[13]	$\pm 7.10^p 16$		72Ya08	DPAD	$\omega=56.2\ 13\text{Mr/s}$	metallic $^{208}\text{Pb}$ (pulsed $\alpha$ , ); $H_o=21.03\ 10\text{kG}$
$^{211}_{84}\text{Po}$	1064	16ns	[15/2]	$\pm 0.38^p 15$		72Fa17	IPAD		$^{208}\text{Pb}$ (pulsed $\alpha$ , ); $H_o=16.6\text{kG}$
$^{211}_{85}\text{At}$	1416	50ns	[21/2]	$\pm 9.42^{dkp} 17$		72In03	DPAD		$^{209}\text{Bi}$ (pulsed $\alpha$ , ); $H_o=21.0\text{kG}$
$^{211}_{85}\text{At}$	4816	$4.2\mu\text{s}$	[39/2, 41/2]	$\pm 14.0\ 14$ , $\pm 14.8\ 14$		71Ma70	DPAD		pulsed $^4\text{He}$ or $^{16}\text{O}$ on separated Hg, Tl, Pb, Bi
$^{212}_{86}\text{Rn}$	$\sim 1700$	$1.0\mu\text{s}$	[8]	$\pm 7.12\ 24$		71Ma70	DPAD		pulsed $^4\text{He}$ or $^{16}\text{O}$ on separated Hg, Tl, Pb, Bi
$^{222}_{86}\text{Rn}$	186	320ps	[2]	$+0.90\ 14$		70Or02	PAC	$\Delta\theta=-1.59^\circ \ddagger$	$\alpha$ -decay recoils from Ra or $\text{RaCl}_2$ in Gd, Pb, $\text{U}_2\text{O}_3$ ; $H_o=27.6\ 5\text{kG}$
								‡Corrected for beam deflection	
$^{223}_{88}\text{Ra}$	50	630ps	[3/2]	$+0.42\ 6$		70Le13	PAC	$\omega\tau=34\ 3\text{mr}$	liquid $^{227}\text{Ac}$ in $\text{HNO}_3$ ; $H_o=28\text{kG}$
$^{233}_{92}\text{U}$	gs	162ky	(5/2)			58Da21	$\alpha$ AO	Anisotropy negative; $P\sim\pm 0.03\text{cm}^{-1}$	$\text{UO}_2\text{Rb}(\text{NO}_3)_3$
$^{233}_{92}\text{U}$	gs	162ky	(5/2)			60Ro27	$\alpha$ AO		$\text{UO}_2\text{Rb}(\text{NO}_3)_3$
$^{235}_{92}\text{U}$	gs	710My	(7/2)			68Ma42	$\alpha$ AO	$\alpha$ 's emitted perpendicular to alignment axis	$\text{UO}_2\text{Rb}(\text{NO}_3)_3$
$^{237}_{93}\text{Np}$	gs	2.1My	(5/2)		positive	58Da21 61Ha34	$\alpha$ AO	Anisotropy negative; $A<0$ , $P>0$	$\text{NpO}_2\text{Rb}(\text{NO}_3)_3$ crystal
$^{237}_{93}\text{Np}$	60	63ns	[5/2]	$+3.5 \pm 5$		55Kr02	DPAC	$\alpha$ 's emitted parallel to nuclear spin	liquid source in 1N $\text{HClO}_4$
$^{237}_{93}\text{Np}$	60	63ns	[5/2]	$\pm 2.45^p 10$		57Kr52 66He13	DPAC	‡Solutions may have been imperfect	concentrated $^{241}\text{AmCl}_3$ in HCl $H_o=41.1\ 4\text{kG}$ ; used $\beta(20^\circ\text{C})=1.28\ 4$ and $G_2=0.45$
$^{237}_{93}\text{Np}$	60	63ns	[5/2]	$+1.90\ 15$		67Gu08	DPAC IPAC	‡Unit given as MHz	$\text{AmO}$ in 6N HCl; $H_o=12.5\text{kG}$ , $\beta=1.68\ 11$
$^{239}_{93}\text{Np}$	75	1.40ns	[5/2]	$+1.98\ 24$		67Gu08	IPAC	$\omega=-76.5\ 35\text{Mr/s}$ $g^{239}(75)/g^{237}(60)=1.04\ 9$	$\text{AmO}$ in 6N HCl; $H_o=18.5\text{kG}$ , $\beta=1.68\ 11$
$^{253}_{99}\text{Es}$	gs	20.5d	[7/2]	$\pm 2.7\ 13$		70So09 62Na14	$\alpha$ AO	$A_{ave}=0.26\ 3\text{cm}^{-1}$	Es <sup>3+</sup> in NES crystal; used $\langle r^{-3} \rangle_{sf}=10.92\text{au}$

\*Polarization or Sternheimer correction included.

<sup>a</sup> Half-life used by authors not known, therefore  $\mu$  not corrected to quoted half-life.

<sup>b</sup> Spin-value used by authors not known, therefore  $\mu$  not corrected to quoted spin.

<sup>c</sup> Recalculation of earlier data.

<sup>d</sup> Diamagnetic correction included.

<sup>e</sup> Includes Knight shift correction.

<sup>f</sup> Preliminary value from meeting abstract, report, thesis, or private communication.

**Table K: Nuclear Moments by Coulomb Excitation Reorientation and Inelastic Electron-Scattering**

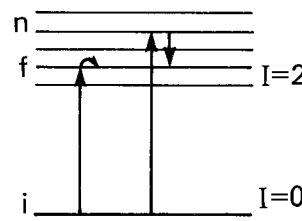
The following table lists values of nuclear moments derived from Coulomb excitation reorientation measurements and inelastic electron-scattering experiments. The possibility of determining nuclear electric quadrupole moments by the reorientation effect in Coulomb excitation was first proposed by Breit, [55Br64] and [56Br69]. He explained the effect as an interaction of the excited-state quadrupole moment with the electromagnetic field of the projectile after the nucleus is Coulomb-excited by the projectile. The name is derived from considering the effect as a second-order perturbation process where the E2 multipole interaction first causes a transition from the ground state to an excited state of the nucleus and then causes a transition from one magnetic sub-level to another of the same state, i.e. a reorientation of the nuclear axis. This is pictorially represented in figure 1. The second order excitation probability then depends on the static quadrupole moment of the excited state.

In Coulomb excitation the projectile does not penetrate the nucleus and the interactions with the nucleus are reasonably well understood. The major assumptions made in a semi-classical treatment are that 1) the projectile orbit can be treated classically and 2) that perturbation theory can be applied. For the first assumption to apply, the energy of the projectile must be low enough so that it can be described by a 'wave-packet' which is small with respect to nuclear dimensions. If the dimensionless parameter,  $\eta$ , is defined by:

$$\eta = 2\pi a/\lambda = 2\pi Z_1 Z_2 e^2 / h v_\infty \quad (1)$$

where  $a$  is 1/2 the distance of closest approach in a head-on collision;  $\lambda = h/mv_\infty$ , the deBroglie wavelength of the projectile;  $v_\infty$ , the velocity of the projectile at infinity; and  $Z_1$  and  $Z_2$  are the projectile and target charges respectively, then this condition is fulfilled when  $\eta \gg 1$ . For the energies used in Coulomb excitation, where  $2a$  is greater than the nuclear radius, this condition is usually satisfied. A

FIGURE 1. A pictorial representation of the reorientation effect. The E2 multipole interaction first causes a transition to an excited state and then a transition from one sub-level to another of the excited state.



further requirement that the projectile may be treated as a classical particle moving in a hyperbolic orbit is that the energy loss in the excitation process be small compared to the incident energy. If we define an adiabaticity parameter:

$$\xi = 2\pi a \Delta E / h v_\infty \equiv \tau_{\text{collision}} / \tau_{\text{nuclear}} \quad (2)$$

where  $\Delta E$  is the excitation energy between the initial and final states, then for  $\xi \ll 1$ , the excitation process can be treated as a sudden one and this condition obtains. For a classical particle,  $\xi = 0$ . For  $\xi \gg 1$ , the process is adiabatic and the excitation probabilities vanish. The second assumption requires that the first-order excitation probabilities be small.

For a classical projectile, the angular distribution of the elastically scattered particle is given by the Rutherford cross section:

$$d\sigma_R = (a^2/4) \sin^{-4}(\theta/2) d\Omega \quad (3)$$

where  $\theta$  is the scattering angle; see figure 2. To obtain the cross section for Coulomb excitation of the nucleus, the Rutherford cross section is multiplied by the probability of exciting the nucleus to the final state. If the excitation probabilities are small, the first-order transition amplitudes can be calculated from:

$$b_{if}^{(1)} = (2\pi i/h) \int_{-\infty}^{\infty} \langle f | H_{\text{int}} | i \rangle \exp[(2\pi i/h)(E_f - E_i)t] dt \quad (4)$$

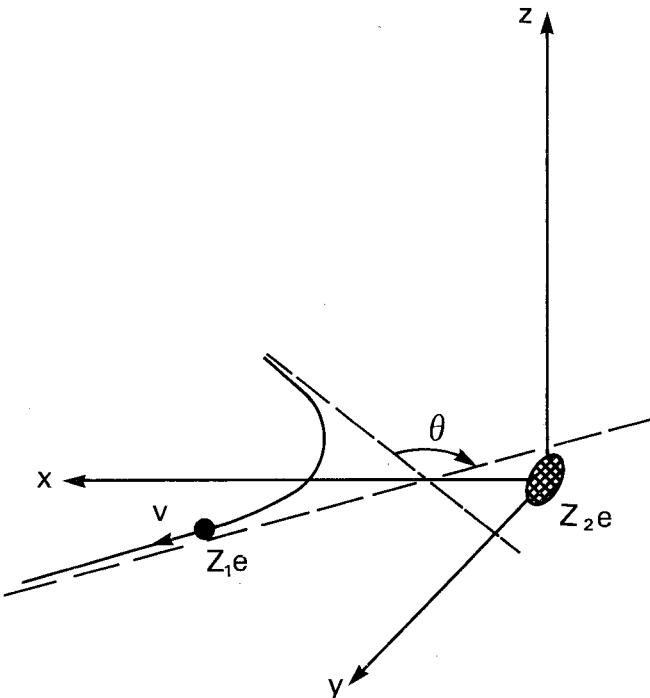


FIGURE 2. Focal-coordinate system of the scattering of a classical projectile of charge  $Z_1e$  by a nucleus of charge  $Z_2e$ . The path of the projectile is in the  $xy$ -plane and  $\theta$  is the scattering angle.

where  $H_{\text{int}}$  denotes the time-dependent electromagnetic interaction and  $E_f$  and  $E_i$ , the energies of the final and initial states. In the semi-classical treatment,  $H_{\text{int}}$  is expanded in multipoles. The monopole interaction gives rise to the Rutherford scattering which is already accounted for by considering the projectile moving in a classical hyperbolic orbit. The magnetic multipole excitation amplitudes are smaller than the electric ones by the factor  $v/c$ , which is small for the energies of the projectiles used in Coulomb excitation. Magnetic excitation is therefore negligible except when the electric matrix elements vanish.

To first order, the electric  $E\lambda$  multipole excitation amplitudes can be shown to be:

$$b_{if}^{(1)} = -i(-1)^{I_i-M_i} \left( \frac{8\pi^2 Z_1 e}{hv_\infty a^\lambda} \right) \frac{\langle I_i | \text{ME}\lambda | I_f \rangle}{(2\lambda+1)} \\ \times \sum_{\mu} \begin{pmatrix} I_i & \lambda & I_f \\ -M_i & \mu & M_f \end{pmatrix} Y_{\lambda\mu}(\pi/2, 0) I_{\lambda\mu}(\theta, \xi) \quad (5)$$

where the reduced nuclear matrix element is defined by:

$$\langle I_i | \text{ME}\lambda | I_f \rangle \equiv (-1)^{I_i-M_i} \begin{pmatrix} I_i & \lambda & I_f \\ -M_i & \mu & M_f \end{pmatrix}^{-1} \\ \times \langle I_i M_i | \int r_2^\lambda \rho(r_2) Y_{\lambda\mu}(\Omega_2) d^3r_2 | I_f M_f \rangle \quad (6)$$

with  $\rho(r_2)$  the nuclear charge density and where the  $Y_{\lambda\mu}(\pi/2, 0)$  and  $I_{\lambda\mu}(\theta, \xi)$  are functions of the projectile orbits, see [68De34], page 7\*. The functions  $Y_{\lambda\mu}(\pi/2, 0)$  and  $I_{\lambda\mu}(\theta, \xi)$  are defined and tabulated in references [60Al23] and [56Al54]. This amplitude leads to the first order differential excitation cross section:

$$d\sigma = P_{i \rightarrow f}^{(1)} d\sigma_R = (2I_i + 1)^{-1} \sum_{M_i M_f} |b_{if}^{(1)}|^2 d\sigma_R \\ = \frac{64\pi^4 Z_1^2 e^2}{h^2 v_\infty^2 a^{2\lambda}} \frac{B(E\lambda, I_i \rightarrow I_f)}{(2\lambda+1)^3} \\ \times \sum_{\mu} |Y_{\lambda\mu}|^2 |I_{\lambda\mu}|^2 a^2 (4\sin^4 \theta/2)^{-1} d\Omega \quad (7)$$

$$\text{where } B(E\lambda, I_i \rightarrow I_f) \equiv (2I_i + 1)^{-1} |\langle I_i | \text{ME}\lambda | I_f \rangle|^2 \quad (8)$$

In order to evaluate the reorientation effect, the calculations for the excitation must be carried out to second order.

$$b_{if}^{(2)} = b_{if}^{(1)} + \sum_n b_{inf} \quad (9)$$

where

$$b_{inf} = (ih/2\pi)^{-2} \int_{-\infty}^{\infty} \langle f | H_{\text{int}} | n \rangle \exp[(2\pi i/h)(E_f - E_n)t] dt \\ \times \int_{-\infty}^{\infty} \langle n | H_{\text{int}} | i \rangle \exp[(2\pi i/h)(E_n - E_i)t'] dt' \quad (10)$$

The sum extends over all intermediate states "n", including the initial and final states. This double integral can be simplified, see Alder [56Al54], p469, so that the total amplitude to second order is of the form:

$$b_{if}^{(2)} = A[i \langle I_i | \text{ME}\lambda | I_f \rangle Y_{\lambda\mu} I_{\lambda\mu} / (v_\infty a^\lambda)] \\ + \sum_n B \langle I_i | \text{ME}\lambda_1 | I_n \rangle \langle I_n | \text{ME}\lambda_2 | I_f \rangle \\ \times (\alpha_{\lambda, -\mu} + i\beta_{\lambda, -\mu}) / v_\infty^2 a^{\lambda_1 + \lambda_2}] \quad (10)$$

where  $A$  and  $B$  are functions of  $\lambda$ ,  $Z_1$ ,  $Z_2$ ,  $I_i$ ,  $I_f$ ,  $M_i$ ,  $M_f$  and where  $\alpha$  and  $\beta$  are functions of the projectile parameters  $\theta$ ,  $\lambda_j$ ,  $\mu_j$ , and  $\xi_j$ . The last three quantities, with  $j=1$  and 2, are defined for the transitions  $i \rightarrow n$  and  $n \rightarrow f$  respectively. The differential cross section to second order is then:

$$d\sigma = [P^{(11)} + P^{(12)} + O(P^{(22)})] d\sigma_R \\ = d\sigma_R (2I_i + 1)^{-1} \sum_{M_i M_f} [(b_{if}^{(1)})^2 \\ + 2\text{Re}(b_{if}^{(1)} \sum_n b_{inf}) + O(\text{ME}\lambda)^4] \quad (11)$$

For the case of  $\lambda=2$ , the crossover term is seen to contain terms proportional to  $[B(E2, I_i \rightarrow I_f)]Q$ , since, for "n" equal to "i" or "f",

$$Qe = (16\pi/5)^{1/2} [I(2I-1)/(2I+1)(2I+3)(I+1)]^{1/2} \\ \times \langle I | \text{ME}2 | I \rangle. \quad (12)$$

In order to account for the different velocities of the projectile before and after the excitation, the semiclassical expressions can be symmetrized by replacing  $v_\infty \rightarrow \sqrt{v_i v_f}$ ,  $a \rightarrow Z_1 Z_2 e^2 \times (1 + A_1/A_2)/A_1 v_i v_f$ ,  $\xi \rightarrow \eta_f - \eta_i$  and by multiplying the resulting excitation probability by a factor  $v_f/v_i$ . With these substitutions, the semiclassical Coulomb excitation probabilities closely approximate the quantum mechanical results; see [56Al54, 65Bi14].

The application of perturbation theory assumes that the probability of excitation of any level is small and that higher order processes are negligible. This is true, in general, for excitation by p, d, and  $\alpha$ 's but not for higher  $Z$  projectiles nor for target nuclei with large transition probabilities between excited states and the ground or final states. For those cases, multiple Coulomb excitation becomes important. The nuclear system then interacts strongly with the time-dependent electromagnetic fields produced by the

\*Note, in the definition of  $X$ , equation (12) of [68De34],  $(\lambda+1)!$  should be replaced with  $(\lambda-1)!$

projectile and many levels are excited simultaneously. Some higher levels can even be more strongly excited than lower lying ones. If multiple excitation effects are important, the final state amplitudes for the individual levels can be obtained by solving a set of coupled Schrödinger equations. The calculation of the reorientation effect must be carried out for the particular nucleus and for the actual bombarding conditions. All of the available information on the energies and spins of the individual nuclear levels which can contribute and on the matrix elements connecting them (experimentally determined or calculated from some model) must be used as input data in order to determine the quadrupole moments from the reorientation measurements. A representation of the types of virtual transitions which must be considered in such calculations is given in figure 3. Many  $Q$ -values have been determined using the deBoer-Winther computer code for the differential cross sections for multiple Coulomb excitation [65Wil4 or 66Al22]. This code can handle up to 10 nuclear levels with a total of 90 substates, for  $\lambda = 2$ . One of the major sources of uncertainty in the determination of  $Q$ 's from such calculations is the relative phases of the matrix elements for excitation via different levels. In many cases, several values of  $Q$  are quoted, one for each of the different combinations of signs possible.

A code is also available to compute the angular

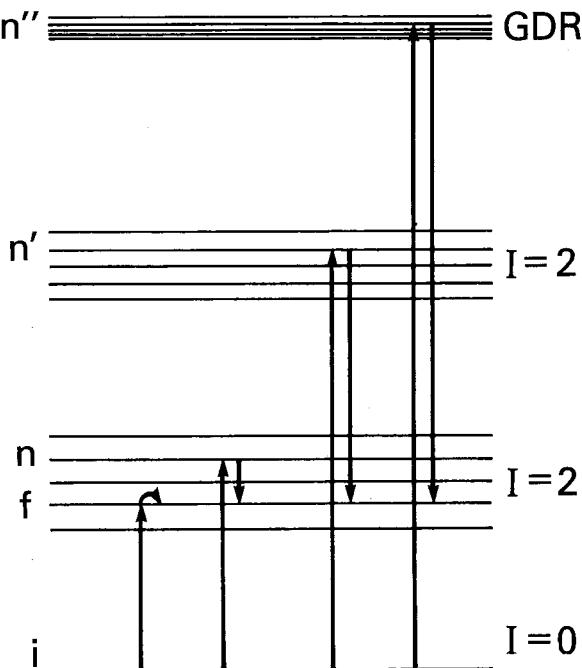


FIGURE 3. A representation of some of the kinds of transitions which must be included in the multiple Coulomb excitation of level ' $f$ ' from level ' $i$ '. The first two represent the reorientation transitions: the third, a competing excitation of the level through a higher,  $I=2$  level; and the fourth, an excitation of the level through the giant dipole resonance.

distribution of the deexcitation  $\gamma$ -rays. When observing only the  $\gamma$ -ray angular distribution from a particular level, the situation is more complicated than when the scattered particles are observed. The level is not only populated by Coulomb excitation directly to that level but also by Coulomb excitation to higher levels with subsequent unobserved cascades of conversion electrons or  $\gamma$ -rays to the level. The contribution of these additional real transitions must be subtracted. It is therefore necessary to know the L-pole  $\gamma$ -transition rates and internal conversion coefficients for all transitions which could occur as well as the angular correlations between them if the reorientation effect is measured via the deexcitation  $\gamma$ -ray angular distributions.

Several graphs are presented in deBoer and Eichler's article, [68De34], which are useful in establishing the values of some experimental variables. The bombarding energy must be kept small enough to insure that nuclear interactions, other than Coulomb, are not important. Such interactions are not well enough understood, generally, to be accounted for with sufficient accuracy. Two arbitrary limits were chosen by the authors to define a "maximum safe bombarding energy" for their plot of  $E_{\max}$  as a function of the target mass,  $A_2$ , for values of the projectile mass,  $A_1$ , from 2 to 64 [68De34, figure 7]. The minimum distance between the two nuclear surfaces in a head-on collision must be 1) greater than 3 Fermi and 2) larger than the deBroglie wavelength of the projectile at infinity. The "safe bombarding energy" increases slowly with  $A_1$  and  $A_2$ . In figure 8, [68De34], a similar plot of the corresponding values of  $\eta$  is given. A third useful graph, figure 9 in the same article, shows the interaction strength,  $X_{i \rightarrow f}$ , as a function of  $A_1$  and  $A_2$  for the excitation of the first  $2^+$ -level by a projectile at the "maximum safe bombarding energy." The plot assumes a  $B(E2, 0^+ \rightarrow 2^+)$ -value of  $1.0 \text{ e}^2 \text{b}^2$ . For values of  $X < 0.1$ , the use of second order perturbation theory yields excitation probabilities which are accurate to about 1%. The interaction strengths increase rapidly with  $A_1$  so that second order perturbation theory may not be justified and a multiple-excitation calculation be required for heavy projectiles.

For the case of  $^{114}\text{Cd}$ , on which the earliest reorientation experiments were performed and on which there has been very much activity, the "maximum safe bombarding energies," corresponding values of  $\eta$ , and the interaction strengths,  $X_{i \rightarrow f}$ , for a  $B(E2, 0^+ \rightarrow 2^+) = 1.0 \text{ e}^2 \text{b}^2$  obtained from the graphs in [68De34] are presented in table 1. For the 558keV level, the actual  $B(E2) = 0.51 \text{ e}^2 \text{b}^2$ . From the table it is seen that second order perturbation calculations would be applicable for  $^2\text{H}$ -projectiles under 3MeV and possibly also for  $^4\text{He}$  under 11MeV, but not for the heavier projectiles. For these, multiple Coulomb excitation must be considered. In the paper by

TABLE 1. Maximum safe bombarding energies, corresponding  $\eta$ 's, and interactions strengths,  $X_{i \rightarrow f}$ , for projectiles on  $^{114}\text{Cd}$ , as taken from the graphs in [68De34]

Projectile	Maximum safe bombarding energy (MeV)	$\eta$	$X_{i \rightarrow f}^{\dagger}$
$^2\text{H}$	3	5	0.07
$^4\text{He}$	11	9	0.22
$^8\text{C}$	23	17	0.50
$^{16}\text{O}$	50	33	0.85
$^{32}\text{S}$	100	65	1.5

$\dagger$ Assumed  $B(E2,0 \rightarrow 2) = 1.0 \text{ e}^2 \text{b}^2$

Berant et al., [71Be36], there is a discussion of the many papers on  $^{114}\text{Cd}$  with an attempt to establish a best value for the static quadrupole moment of the 558keV level, which they give as  $-0.32 \pm 8\text{b}$ . In the same paper they mention that with a precision level of 1%, they observe no deviations from pure Coulomb excitation for  $^4\text{He}$ -projectiles up to 10MeV, but that deviations do occur for  $^{16}\text{O}$  above about 46MeV. These are not consistent with the values in table 1. These "safe bombarding energies" should, therefore, be considered merely as a guide. It has been suggested that the lack of nuclear interactions should always be checked out experimentally by performing the reorientation experiments at at least two different bombarding energies.

Quadrupole moments can be obtained either by making high precision absolute cross section measurements or by studying the relative excitation of a level under different bombarding conditions. For example, eq (11) can be written as  $d\sigma \approx P^{(11)}(1+r)d\sigma_R$  where, for the most frequently encountered case, one with  $I_i=0$ ,  $I_f=2$ ,  $\lambda=2$ , no other states excited and for low excitation energies,  $\Delta E$ :

$$r \equiv P^{(12)}/P^{(11)} \approx A_1 \Delta E \langle f || \text{ME}2 || f \rangle K(\xi, \theta) \times [Z_2(1+A_1/A_2)]^{-1}. \quad (12)$$

Here the  $A$  are in amu,  $\Delta E$  in MeV, and  $\langle f || \text{ME}2 || f \rangle$  in eb.  $K$  is a function of the projectile parameters:  $Y_{2,\mu}$ ,  $I_{2,\mu}$ ,  $\beta_{2,-\mu}$ . A plot of  $K$  as a function of  $\xi$  for different scattering angles can be found in deBoer and Eichler, [68De34], p33. For a given angle,  $K$  is a slowly varying function of  $\xi$ . It is a maximum for  $\theta = \pi$ . At backward angles,  $K$  is a maximum for small values of  $\xi$ .  $r$  is seen to be proportional to the excitation energy of the level and to the mass of the projectile used. However, the ratio  $\Delta E/E$  must be kept small ( $\xi < 1$ ) if the projectile is to be treated semiclassically. The  $P^{(11)}$  can be calculated from measurements of the lifetimes of the excited states. Since typical values of  $r$  are of the order of 0.10, the  $B(E2)$ 's and absolute cross sections must be known to a few percent or better in order to determine the quadrupole moment.

For relative excitation measurements, the ratio of the cross sections for two different bombarding conditions, a and b, can be expressed as:

$$d\sigma_a/d\sigma_b \approx (P_a^{(11)}/P_b^{(11)}) (1 + r_a - r_b) \quad (13)$$

with

$$r_a - r_b \equiv \Delta E \langle 2+ || \text{ME}2 || 2+ \rangle \times [A_{1a}K(\xi_a, \theta_a) - A_{1b}K(\xi_b, \theta_b)]/Z_2 \quad (14)$$

for  $A_1 \ll A_2$ ,  $P_a^{(11)}/P_b^{(11)}$  is independent of the nuclear transition matrix element and is easily calculated. The ratio of the cross sections can be made more sensitive to the quadrupole moment by choosing the projectile parameters,  $A_1$ ,  $\xi$ , and/or  $\theta$ , to make the term in the square brackets in (14) as large as possible.

The excitation cross sections are measured either by detecting the elastically and inelastically scattered projectiles or by observing the deexcitation of the nucleus, usually in coincidence with the scattered projectile. In the first type of experiment, the major difficulties are those associated with trying to separate the elastic and inelastic peaks. At high excitation energy, the excitation probabilities are small and it is difficult to observe the small inelastic peak in the tail of the elastic peak. At low excitation energies, the excitation probabilities are larger but the resolution of the two peaks frequently presents problems.

In the second type of experiment, the deexcitation  $\gamma$ 's are measured in coincidence with the scattered projectile. A schematic diagram of a possible arrangement is shown in figure 4. The  $p\gamma$  coincidence rate is given by:

$$\text{C.R.} = \epsilon_\gamma \sum_{n=1}^{\infty} f_n (d\sigma_n/d\Omega)_{lab} / \sum_{n=0}^{\infty} (d\sigma_n/d\Omega)_{lab} \quad (15)$$

where  $\epsilon_\gamma$  is the counting efficiency for  $\gamma_{f \rightarrow i}$ ;  $f_n$ , the fraction of decays of state  $n$  which give rise to a  $\gamma_{f \rightarrow i}$ ;

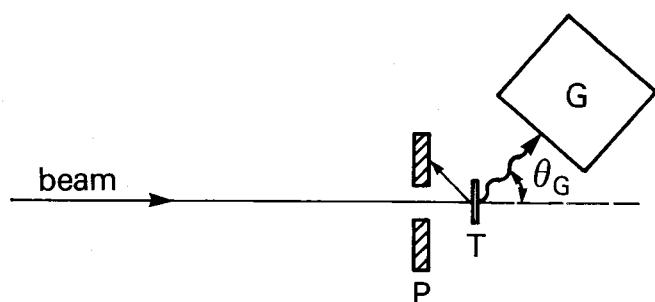


FIGURE 4. A schematic view of an experimental arrangement for the detection of  $\gamma$ -rays in coincidence with back-scattered projectiles. T represents the target; P, an annular particle detector; and G, the  $\gamma$ -ray detector at an angle  $\theta_G$  to the beam.

$(d\sigma_n/d\Omega)_{lab}$ , the differential excitation cross section for the state  $n$ , in the laboratory system. When only one level is excited and if that level decays solely by  $\gamma$ -emission, the coincidence rate is approximately  $\epsilon_\gamma P_{i \rightarrow f}$ . The counting efficiency,  $\epsilon_\gamma$ , must be corrected for the anisotropic distribution of the deexcitation  $\gamma$ . The effect of the anisotropy can be reduced by the proper choice of  $\theta_C$  and the distance of the  $\gamma$ -counter from the target.

The measurement of the scattering cross section as a function of energy is made difficult by the small dependence of  $K$  on  $\xi$ . These experiments require great accuracy if  $Q$  is to be determined from the measurements.

Several moments have been determined by the measurement of the reorientation effect in the projectile. This is an important mode of excitation for heavy projectiles on light nuclei. An approximate expression for this effect can be found by replacing  $Z_2$  by  $Z_1$  in equation (12).

There are several possible sources of errors which may need to be considered in the determination of  $Q$ -values from Coulomb excitation reorientation measurements in addition to those already mentioned. Among these are: deorientation caused by the atomic electrons, relativistic corrections to the motion of the projectile, the attenuation of the angular distributions by the interaction of the excited state moments with the electronic fields, and the recoil of the nucleus which could give rise to Doppler-shifted energies as well as additional  $\gamma$ -distribution attenuations.

This simplified discussion of the Coulomb excitation reorientation relies heavily on the material presented in [68De34, 65Bi14, 60Al23, 59Br23, and 56Al54], which should be referred to for more detailed descriptions of the actual measurements and calculations of the quadrupole moments therefrom. A collection of reprints of the important papers on Coulomb Excitation, including the deBoer-Winther computer code for multiple Coulomb excitation which is used in many reorientation calculations, is found in [66Al22]. Biedenharn and Brussard, [65Bi14], also discuss some of the features of Coulomb excitation using electrons.

Recently, Lightbody and Penner, see [72Li12], proposed the calculation of static quadrupole moments from high-resolution inelastic electron-scattering measurements. To date, the quadrupole moments derived from these measurements depend on the use of an oversimplified nuclear model for the states involved. The deduced  $Q$ -values for eight nuclei in the Cr and Cd regions, are in reasonably good agreement with the Coulomb excitation reorientation measurements on the same nuclei. The physical basis for the success of this model in giving the moments is not understood at this time. The electron-scattering experiments yield the sign of the quadrupole moments and are not plagued with the uncertainties connected with the relative signs of the matrix elements which are present in the reorientation calculations.

The last systematic literature search for data included in the table was done in early 1972.

## Explanation of Table K

Nucl.	Chemical symbol with $Z-$ and $A-$ number
Level	Energy, in keV, of the level for which information is given Ground state levels are indicated by gs.
$T_{1/2}$	Half-life of the level The value quoted is taken from Table of Nuclear Half-Lives (68Ma49), Nuclear Data Sheets (through Volume B5), Table of Isotopes (67LeHo), or it is the value used in the referenced article.
$I$	Nuclear spin, in units of $\hbar/2\pi$ Values enclosed in ( )'s have been determined by resonance or spectroscopic techniques. Values enclosed in [ ]'s have been inferred from decay characteristics.
$\mu$	Nuclear magnetic dipole moment, in nuclear magnetons Nuclear magnetic octupole moments, $\Omega$ , in nuclear magneton-barns, have also been tabulated in this column. These have been obtained from elastic and inelastic electron-scattering cross sections. The values, which are model-dependent, have been enclosed in [ ]'s.
$Q$	Nuclear electric quadrupole moment, in barns, as given by the experimenter Those values marked by an asterisk, *, indicate that the experimenter has made some polarization or Sternheimer correction in computing the moment.  Values which are enclosed in [ ]'s, have been derived from elastic and inelastic electron-scattering cross sections and are model-dependent.  When two values of $Q$ are given, for CExRO measurements, the first represents the value obtained assuming constructive interference; the second, destructive interference of the matrix elements.  Values of the hexadecapole moment, in barns <sup>2</sup> , are also tabulated in this column.
Refer.	Reference key number
Method	Codes used to designate the specific techniques are: CExRO Coulomb excitation reorientation eSc electron scattering
Measured Quantity	Measured quantities from which moments are derived
Environment and Comments	Nature of materials used, assumptions made, and comments

**Table K: Nuclear Moments by  
Coulomb Excitation Reorientation and Inelastic Electron-Scattering**

Nucleus	Level (keV)	$T_{1/2}$	$I$	$\mu$	$Q$	Refer.	Method	Measured Quantity	Environment and Comments
$^7_3\text{Li}$	gs	—	(3/2)	[ $\Omega = +0.091$ 16]		66Ra29	eSc	$\Omega/\mu = 0.028$ 5b	
$^7_3\text{Li}$	gs	—	(3/2)	[ $[-0.302^\circ]$ ]		69Vi02	eSc		
$^9_4\text{Be}$	gs	—	(3/2)	[ $\Omega = -0.035$ ]		65Gr18	eSc		
$^9_4\text{Be}$	gs	—	(3/2)	[ $\Omega = -0.041$ 6]		66Ra29	eSc	$\Omega/\mu = 0.035$ 5b	
$^{10}_5\text{B}$	gs	—	(3)	[ $\Omega \leq 0.029$ ]		66Ra29	eSc	$\Omega/\mu \leq 0.016$ b	
$^{10}_5\text{B}$	gs	—	(3)	[ $[\pm 0.0675^\circ]$ ]		69Vi02	eSc		
$^{11}_5\text{B}$	gs	—	(3/2)	[ $\Omega = +0.081$ ]		65Gr18	eSc		
$^{11}_5\text{B}$	gs	—	(3/2)	[ $\Omega = +0.078$ 5]		66Ra29	eSc	$\Omega/\mu = 0.029$ 5b	
$^{11}_5\text{B}$	gs	—	(3/2)	[ $[\pm 0.032^\circ]$ ]		69Vi02	eSc		
$^{12}_6\text{C}$	14100	?	[4]		[ $-0.201$ ]	71Na14	eSc		Used $\langle r^2 \rangle^{1/2} = 2.42$ F and $\langle r^4 \rangle^{1/4} = 2.68$ F
[ $Q_4^i = +0.00215\text{b}^2$ ]									
$^{20}_{10}\text{Ne}$	1630	0.7ps	[2]		-0.27 11	69Sc08	CExRO		Ne gas( $^{32}\text{S}, \text{S}'$ )
$^{20}_{10}\text{Ne}$	1630	0.7ps	[2]		-0.24 3	70Na07	CExRO		CEx with Ne on $^{120}\text{Sn}$ ; $^{130}\text{Te}; ^{148}\text{Sm}$
$^{22}_{10}\text{Ne}$	1275	3ps	[2]		-0.21 6	69Sc08	CExRO		$^{22}\text{Ne}$ gas( $^{32}\text{S}, \text{S}'$ )
$^{22}_{10}\text{Ne}$	1275	3ps	[2]		-0.21 4	70Na07	CExRO		CEx with Ne on $^{130}\text{Te}; ^{148}\text{Sm}$
$^{24}_{12}\text{Mg}$	1368	1ps	[2]		-0.26 8	68Ba44	CExRO		Mg( $^{32}\text{S}, \text{S}'$ )
$^{24}_{12}\text{Mg}$	1368	1ps	[2]		-0.243 35	70Ha04	CExRO		Mg( $^{35}\text{Cl}, \text{Cl}'$ )
$^{24}_{12}\text{Mg}$	1368	1ps	[2]		-0.305 64	71Vi01	CExRO		Mg( $^{16}\text{O}, \text{O}'$ )
$^{27}_{13}\text{Al}$	gs	—	(5/2)		[ $\pm 0.146$ ]	67St01	eSc		
$^{27}_{13}\text{Al}$	gs	—	(5/2)	[ $\Omega = \pm 0.34^\circ$ 9]		71de55	eSc		
$^{28}_{14}\text{Si}$	1779	0.5ps	[2]		+0.17 5	69Ha31	CExRO		$^{62}\text{Ni}(^{28}\text{Si}, \text{Si}')$
$^{28}_{14}\text{Si}$	1779	0.5ps	[2]		+0.22 9	69Pe08	CExRO		Si( $^{32}\text{S}^{6+}, \text{S}'$ )
$^{28}_{14}\text{Si}$	1779	0.5ps	[2]		+0.11 $\pm$ 5	70Na05	CExRO		Si( $^{206}\text{Pb}, \text{Pb}'$ )
								‡Assumed $Q_{2+}(^{206}\text{Pb}) = (0.05) \times  Q_{\text{rot}} $	
$^{32}_{16}\text{S}$	2237	0.25ps	[2]		-0.05	70Ha24	CExRO		$^{50}\text{Ti}(^{32}\text{S}, \text{S}')$
					to +0.25				
$^{32}_{16}\text{S}$	2237	0.25ps	[2]		-0.20 $\pm$ 6	70Na05	CExRO		S( $^{206}\text{Pb}, \text{Pb}'$ )
								‡Assumed $Q_{2+}(^{206}\text{Pb}) = (0.05) \times  Q_{\text{rot}} $	
$^{36}_{18}\text{Ar}$	1980	?	[2]		+0.11 $\pm$ 6	71Na06	CExRO		$^{206}\text{Pb}(150\text{MeV} ^{36}\text{Ar}, \text{Ar}')$
								‡Assumed $Q_{2+}(^{206}\text{Pb}) = (0.05) \times  2 Q_o/7 $	
$^{40}_{18}\text{Ar}$	1460	0.8ps	[2]		+0.01 $\pm$ 4	70Na05	CExRO		CEx with $^{206}\text{Pb}, ^{130}\text{Te}, ^{120}\text{Sn}$ on Ar
								‡Assumed $Q_{2+}(^{206}\text{Pb}) = (0.05) \times  Q_{\text{rot}} $	
$^{46}_{22}\text{Ti}$	889	7ps	[2]		-0.19 10	70Ha24	CExRO		$^{46}\text{Ti}(^{35}\text{Cl}^{7+}, \text{Cl}')$
$^{46}_{22}\text{Ti}$	889	7ps	[2]		-0.28 14	71De29	CExRO		$^{46}\text{Ti}(^{16}\text{O}, \text{O}')$
$^{48}_{22}\text{Ti}$	983	3.6ps	[2]		-0.22 8	70Ha24	CExRO		$^{48}\text{Ti}(^{35}\text{Cl}^{7+}, \text{Cl}')$
$^{48}_{22}\text{Ti}$	983	3.6ps	[2]		-0.38 13	71De29	CExRO		$^{48}\text{Ti}(^{16}\text{O}, \text{O}')$
$^{48}_{22}\text{Ti}$	983	3.6ps	[2]		-0.05 $\pm$ 7	71Le17	CExRO		Ti( $^{32}\text{S}, \text{S}'$ )
$^{48}_{22}\text{Ti}$	983	3.6ps	[2]		[ $-0.177$ 8]	72Li12	eSc		
$^{50}_{22}\text{Ti}$	1550	1ps	[2]		-0.02 9	70Ha24	CExRO		$^{50}\text{Ti}(^{32}\text{S}^{6+}, \text{S}')$
$^{50}_{24}\text{Cr}$	783	8.4ps	[2]		$\pm 0.30^\circ$ 9	72To12	CExRO		CEx with 62MeV $^{32}\text{S}$ on thin target

**Table K: Nuclear Moments by  
Coulomb Excitation Reorientation and Inelastic Electron-Scattering — Continued**

Nucleus	Level (keV)	$T_{1/2}$	$I$	$\mu$ or $\Omega$	$Q$	Refer.	Method	Measured Quantity	Environment and Comments
$^{52}_{24}\text{Cr}$	1434	0.90ps	[2]		-0.082 16	72Pe22	eSc		
$^{52}_{24}\text{Cr}$	1434	0.90ps	[2]		-0.09 <sup>p</sup> 13	72To12	CExRO		CEx with $^{12}\text{C}$ , $^{16}\text{O}$ , $^{32}\text{S}$ ; used $Q_{2+}^{50} = 0.304$ 91 b
$^{53}_{24}\text{Cr}$	gs	—	(3/2)		+0.04 6	71Th19	CExRO		CEx with 55; 59MeV $^{32}\text{S}$
$^{54}_{24}\text{Cr}$	834	8.9ps	[2]		-0.12 <sup>p</sup> 10	72To12	CExRO		CEx with $^{12}\text{C}$ , $^{16}\text{O}$ , $^{32}\text{S}$ ; used $Q_{2+}^{50} = 0.304$ 91 b
$^{56}_{26}\text{Fe}$	847	7.4ps	[2]		-0.345 54	70Sc15	CExRO		CEx with 25; 30MeV $^{16}\text{O}$
$^{56}_{26}\text{Fe}$	847	7.4ps	[2]		-0.22 <sup>p</sup> 6	71Le17	CExRO		Fe( $^{32}\text{S}, \text{S}'$ )
$^{56}_{26}\text{Fe}$	847	7.4ps	[2]		-0.23 3	71Th14	CExRO	$(M_{22})_{\text{av}} = 0.306$ 37	CEx with 25; 27.5MeV $^{16}\text{O}$ and 56.0MeV $^{32}\text{S}$ on Fe metal. For $E_0 > 28$ MeV, $M_{22}$ affected by nuclear interactions.
$^{57}_{26}\text{Fe}$	gs	—	1/2			55Tr21			Fe(polarized thermal $n, \gamma$ ). Observed left circular polarization of $7640\gamma$ to g.s.
$^{58}_{28}\text{Ni}$	1450	0.67ps	[2]		-0.12 <sup>p</sup> 13	70Le17	CExRO		CEx with $^{12}\text{C}$ , $^{16}\text{O}$ , $^{32}\text{S}$ on thick target
$^{58}_{28}\text{Ni}$	1450	0.67ps	[2]		-0.16 <sup>p</sup> 10	71Le17	CExRO		$^{58}\text{Ni}(\text{O}, \text{O}')$
$^{60}_{28}\text{Ni}$	1330	0.80ps	[2]		-0.14 <sup>p</sup> 10	71Ch25	CExRO		CEx with $^{16}\text{O}$ , $^{32}\text{S}$
$^{60}_{28}\text{Ni}$	1330	0.80ps	[2]		$\pm 0.00$ 13	69Cl05	CExRO		
$^{60}_{28}\text{Ni}$	1330	0.80ps	[2]		+0.07 <sup>p</sup> 9	71Le17	CExRO		$^{60}\text{Ni}(\text{O}, \text{O}')$
$^{60}_{28}\text{Ni}$	1330	0.80ps	[2]		+0.01 <sup>p</sup> 10	71Ch25	CExRO		CEx with $^{28}\text{Si}$ on $^{62}\text{Ni}$
$^{62}_{28}\text{Ni}$	1170	1.57ns	[2]		{-0.104 18}	72Li12	eSc		CEx with $^{32}\text{S}$ , $^{16}\text{O}$ , $^{12}\text{C}$ on thick target
$^{62}_{28}\text{Ni}$	1170	1.57ns	[2]		$\pm 0.08$ 12	69Ha31	CExRO		$^{62}\text{Ni}(\text{O}, \text{O}')$
$^{62}_{28}\text{Ni}$	1170	1.57ns	[2]		-0.08 <sup>p</sup> 17	70Le17	CExRO		$^{64}\text{Ni}(\text{O}, \text{O}')$
$^{62}_{28}\text{Ni}$	1170	1.57ps	[2]		+0.37 <sup>p</sup> 20	71Ch25	CExRO		
$^{64}_{28}\text{Ni}$	1350	0.78ps	[2]		+0.35 <sup>p</sup> 20	71Ch25	CExRO		
$^{64}_{30}\text{Zn}$	992	2.7ps	[2]		{-0.135 16}	72Li12	eSc		
$^{70}_{30}\text{Zn}$	884	3ps	[2]		{-0.21 3}	72Li12	eSc		
$^{70}_{32}\text{Ge}$	1040	1.3ps	[2]		+0.02 11	69Si15	CExRO		CEx with $^{16}\text{O}$ , $^4\text{He}$ on $^{70}\text{Ge}$ on C foil
$^{74}_{32}\text{Ge}$	596	12ps	[2]		-0.12 16	69Sc32	CExRO		$^{74}\text{Ge}(\text{O}, \text{O}')$
$^{76}_{32}\text{Ge}$	563	17.6ps	[2]		-0.03 17	69Sc32	CExRO		$^{76}\text{Ge}(\text{O}, \text{O}')$
$^{76}_{32}\text{Ge}$	563	17.6ps	[2]		-0.18 14	69Si15	CExRO		CEx with $^{16}\text{O}$ , $^4\text{He}$ on $^{76}\text{Ge}$ on C foil
					or +0.055 140				
$^{104}_{44}\text{Ru}$	358	58ps	[2]		‡		CExRO	‡value attributed to Stelson deleted at request of author	
$^{104}_{46}\text{Pd}$	556	9.7ps	[2]		-0.28 12	70Ch01,	CExRO		CEx with $^4\text{He}$ , $^{16}\text{O}$ on $^{104}\text{Pd}$
$^{104}_{46}\text{Pd}$					or +0.01 10	71Ha08			CEx with $^{16}\text{O}$ , $^{32}\text{S}$ on $^{104}\text{Pd}$
$^{106}_{46}\text{Pd}$	512	12.0ps	[2]		-0.46 6	70Be45	CExRO		CEx with $^4\text{He}$ , $^{16}\text{O}$ on $^{106}\text{Pd}$
$^{106}_{46}\text{Pd}$	512	12.0ps	[2]		or -0.28 6				CEx with $^4\text{He}$ , $^{16}\text{O}$ on $^{106}\text{Pd}$
$^{106}_{46}\text{Pd}$					-0.52 11	70Ch01	CExRO		CEx with $^4\text{He}$ , $^{16}\text{O}$ on $^{106}\text{Pd}$
$^{108}_{46}\text{Pd}$	434	23.8ps	[2]		or -0.25 12	71Ha08	CExRO		CEx with $^4\text{He}$ on $^{108}\text{Pd}$ on C foil; CEx with $^{16}\text{O}$ on $^{108}\text{Pd}$ on Ni or Al; included 4 excited states in analysis
					-0.58 13	71Ha08	CExRO		
					or -0.37 12				

**Table K: Nuclear Moments by  
Coulomb Excitation Reorientation and Inelastic Electron-Scattering — Continued**

Nucleus	Level (keV)	$T_{1/2}$	$I$	$\mu$ or $\Omega$	$Q$	Refer.	Method	Measured Quantity	Environment and Comments
$^{108}_{46}\text{Pd}$	434	23.8ps	[2]		-0.57 <sup>p</sup> 5 or -0.35 5	71Sc30	CExRO		$^{108}\text{Pd}$ metal foils( $^{32}\text{S}$ , S')
$^{110}_{46}\text{Pd}$	374	45.8ps	[2]		-0.83 <sup>p</sup> 19	68St28	CExRO		CEx with $^4\text{He}$ , $^{16}\text{O}$
$^{110}_{46}\text{Pd}$	374	45.8ps	[2]		-0.48 5 or -0.27 5	70Be45	CExRO		CEx with $^{16}\text{O}$ , $^{32}\text{S}$ on $^{110}\text{Pd}$
$^{110}_{46}\text{Pd}$	374	45.8ps	[2]		-0.72 12 or -0.45 12	71Ha08	CExRO		CEx with $^4\text{He}$ on $^{110}\text{Pd}$ on C; CEx with $^{16}\text{O}$ on $^{110}\text{Pd}$ on Ni; included 5 excited states in analysis
$^{110}_{46}\text{Pd}$	374	45.8ps	[2]			71Wa07	CExRO	$Q_{2+}^{110} - Q_{2+}^{108} = -0.11^p 4$ $Q_{2+}^{110} - Q_{2+}^{104} = -0.34^p 7$	CEx with $^4\text{He}$ , $^{12}\text{C}$ , $^{16}\text{O}$ , $^{35}\text{Cl}$ ; assumed constructive interference.
$^{110}_{46}\text{Pd}$	374	45.8ps	[2]		[-0.28 3]	72Pe22	eSc		
$^{106}_{48}\text{Cd}$	633	6ps	[2]		-0.84 $\pm$ 28	70St17	CExRO		CEx with $^4\text{He}$ , $^{16}\text{O}$ , $^{32}\text{S}$ , $^{40}\text{Ar}$
$^{106}_{48}\text{Cd}$	633	6ps	[2]		-0.61 $\pm$ 28 to -0.97 $\pm$	70Kl12	CExRO		‡ Could not separate $\gamma$ 's of $^{106}\text{Cd}$ and $^{108}\text{Cd}$ Based on $Q(^{114}\text{Cd} 2^+ \text{ state}) = -0.38$
$^{108}_{48}\text{Cd}$	633	5ps	[2]		-0.84 $\pm$ 28	70St17	CExRO		CEx with $^4\text{He}$ , $^{16}\text{O}$ , $^{32}\text{S}$ , $^{40}\text{Ar}$
$^{108}_{48}\text{Cd}$	633	5ps	[2]						‡ Corrected for $\gamma\gamma$ attenuation
$^{110}_{48}\text{Cd}$	656	4.6ps	[2]		-0.40 <sup>p</sup> 10	70Gr29	CExRO		CEx with $^4\text{He}$ , $^{16}\text{O}$
$^{110}_{48}\text{Cd}$	656	4.6ps	[2]		-0.24 $\pm$ 10	70St17	CExRO		CEx with $^4\text{He}$ , $^{16}\text{O}$ , $^{32}\text{S}$ , $^{40}\text{Ar}$
$^{110}_{48}\text{Cd}$	656	4.6ps	[2]		-0.42 10 or -0.21 10	71Be36	CExRO		‡ Based on $Q(^{114}\text{Cd} 2^+ \text{ state}) = -0.38$
$^{110}_{48}\text{Cd}$	656	4.6ps	[2]		-0.55 8 or -0.31 7	71Ha08	CExRO		CEx with 8–16MeV $^4\text{He}$ , 37–48MeV $^{16}\text{O}$
$^{112}_{48}\text{Cd}$	617	6.2ps	[2]		‡		CExRO		CEx with $^4\text{He}$ on $^{110}\text{Cd}$ on C; CEx with $^{16}\text{O}$ on $^{110}\text{Cd}$ on Ni; included 5 excited states in analysis
$^{112}_{48}\text{Cd}$	617	6.2ps	[2]		-0.15 $\pm$ 7	70St17	CExRO		‡ value attributed to Stelson deleted at request of author
$^{114}_{48}\text{Cd}$	558	9ps	[2]		-0.49 25	67Si03	CExRO		CEx with $^4\text{He}$ , $^{16}\text{O}$ , $^{32}\text{S}$ on $^{114}\text{Cd}$ ; 7 states included in fit
$^{114}_{48}\text{Cd}$	558	9ps	[2]		-0.90 to -0.54 -0.58 $\pm$ to -0.35 $\pm$	67St03	CExRO		CEx with $^4\text{He}$ , $^{12}\text{C}$ , $^{16}\text{O}$ on $^{114}\text{CdO}_2$ , measured at $\sim 180^\circ$ ; 7 states included in fit
$^{114}_{48}\text{Cd}$	558	9ps	[2]		+0.05 27 or -0.21 28	68Si05	CExRO		‡ Corrected for perturbation of angular correlations by deBoer, quoted in 69Sa27
$^{114}_{48}\text{Cd}$	558	9ps	[2]		-0.68 10 to -0.43 10	69Sa27	CExRO		CEx with $^4\text{He}$ , $^{16}\text{O}$ on $^{114}\text{Cd}$
$^{114}_{48}\text{Cd}$	558	9ps	[2]		-0.53 <sup>p</sup> 17	70An09	CExRO		CEx with $\text{He}^{1+}$ , $\text{C}^{3+}$

**Table K: Nuclear Moments by  
Coulomb Excitation Reorientation and Inelastic Electron-Scattering — Continued**

Nucleus	Level (keV)	$T_{1/2}$	$I$	$\mu$ or $\Omega$	$Q$	Refer.	Method	Measured Quantity	Environment and Comments
$^{114}_{48}\text{Cd}$	558	9ps	[2]		-0.28 $\pm$ 11 to -0.40 $\pm$ 12	70Kl12	CExRO		CEx with $^4\text{He}$ , $^{16}\text{O}$ , $^{32}\text{S}$ on $^{114}\text{Cd}$ on thin C foil or thick Ni foil
$^{114}_{48}\text{Cd}$	558	9ps	[2]		-0.64 19	70Sc15	CExRO	‡Corrected for attenuation of angular correlation	CEx with 25; 30MeV $^{16}\text{O}$ on $^{114}\text{Cd}$ in Cu sandwich
$^{114}_{48}\text{Cd}$	558	9ps	[2]		-0.28 9 or -0.03 9 -0.32 $\pm$ 8	71Be36	CExRO		CEx with 8–16MeV $^4\text{He}$ , 37–48MeV $^{16}\text{O}$ . Deviations from Coulomb interactions observed for $E_a > 10$ MeV and $E_o > 46\text{MeV}$
$^{114}_{48}\text{Cd}$	558	9.2ps	[2]		-0.29 3	72Pe22	eSc	‡Average of $Q$ -values of 70Kl12 and 71Be36.	
$^{116}_{48}\text{Cd}$	513	13.7ps	[2]		-1.16 to -0.70	67St03	CExRO		CEx with $^4\text{He}$ , $^{12}\text{C}$ , $^{16}\text{O}$ on $^{116}\text{CdO}_2$ ; included 5 levels in fit
$^{116}_{48}\text{Cd}$	513	13.7ps	[2]		-0.88 $\pm$ 25	70St17	CExRO		CEx with $^4\text{He}$ , $^{16}\text{O}$ , $^{32}\text{S}$ , $^{40}\text{Ar}$
$^{112}_{50}\text{Sn}$	1257	3ps	[2]		-0.15 $\pm$ 18	70St20	CExRO	‡Based on $Q(^{114}\text{Cd} 2^+ \text{state}) = -0.38$	CEx with $^4\text{He}$ , $^{16}\text{O}$
$^{116}_{50}\text{Sn}$	1290	0.4ps	[2]		+0.09 13	70Kl06	CExRO	‡Based on $Q(^{120}\text{Sn} 2^+ \text{state}) = +0.09 10$	CEx with $^4\text{He}$ , $^{16}\text{O}$ , $^{32}\text{S}$ ; included 4 levels in fit
$^{116}_{50}\text{Sn}$	1290	0.4ps	[2]		+0.07 $\pm$ 16	70St20	CExRO	‡Based on $Q(^{120}\text{Sn} 2^+ \text{state}) = +0.09 10$	CEx with $^4\text{He}$ , $^{16}\text{O}$
$^{116}_{50}\text{Sn}$	1290	0.4ps	[2]		[-0.14 3]	72Pe22	eSc		CEx with $^4\text{He}$ , $^{16}\text{O}$
$^{118}_{50}\text{Sn}$	1230	0.5ps	[2]		-0.23 $\pm$ 16	70St20	CExRO	‡Based on $Q(^{120}\text{Sn} 2^+ \text{state}) = +0.09 10$	CEx with $^4\text{He}$ , $^{16}\text{O}$
$^{120}_{50}\text{Sn}$	1170	0.5ps	[2]		+0.09 10	70St20	CExRO		CEx with $^4\text{He}$ , $^{16}\text{O}$
$^{122}_{50}\text{Sn}$	1140	0.6ps	[2]		-0.28 $\pm$ 17	70St20	CExRO	‡Based on $Q(^{120}\text{Sn} 2^+ \text{state}) = +0.09 10$	CEx with $^4\text{He}$ , $^{16}\text{O}$
$^{124}_{50}\text{Sn}$	1130	0.8ps	[2]		-0.24 15	70Kl06	CExRO		CEx with $^4\text{He}$ , $^{16}\text{O}$ , $^{32}\text{S}$ on $^{124}\text{Sn}$ ; 4 levels included in fit
$^{124}_{50}\text{Sn}$	1130	0.8ps	[2]		+0.07 $\pm$ 17	70St20	CExRO	‡Based on $Q(^{120}\text{Sn} 2^+ \text{state}) = +0.09 10$	CEx with $^4\text{He}$ , $^{16}\text{O}$
$^{122}\text{Te}$	564	7.6ps	[2]		‡		CExRO	‡Value attributed to Stelson deleted at request of author	
$^{124}_{52}\text{Te}$	603	4.3ps	[2]		-0.50 $\pm$ 10 or -0.27 $\pm$ 10	72Kl02, 71Kl06	CExRO		CEx with $^4\text{He}$ , $^{16}\text{O}$ on $^{124}\text{Te}$
$^{126}_{52}\text{Te}$	667	4.4ps	[2]		-0.50 to -0.16	67St16	CExRO		CEx with $^4\text{He}$ , $^{16}\text{O}$
$^{126}_{52}\text{Te}$	667	4.4ps	[2]		-0.20 $\pm$ 9 or -0.00 $\pm$ 9	72Kl02, 71Kl06	CExRO		CEx with $^4\text{He}$ , $^{16}\text{O}$ on $^{126}\text{Te}$
$^{128}_{52}\text{Te}$	743	3.2ps	[2]		-0.40 to -0.01	67St16	CExRO		CEx with $^4\text{He}$ , $^{16}\text{O}$ on $^{128}\text{Te}$
$^{128}_{52}\text{Te}$	743	3.2ps	[2]		-0.07 $\pm$ 9 +0.12 $\pm$ 9	72Kl02, 71Kl06	CExRO		CEx with $^4\text{He}$ , 160 on $^{128}\text{Te}$
$^{130}_{52}\text{Te}$	840	2.0ps	[2]		-0.19 15 or -0.12 15	70Ch01	CExRO		CEx with $^4\text{He}$ , $^{16}\text{O}$ on $^{130}\text{Te}$

**Table K: Nuclear Moments by  
Coulomb Excitation Reorientation and Inelastic Electron-Scattering – Continued**

Nucleus	Level (keV)	$T_{1/2}$	$I$	$\mu$ or $\Omega$	$Q$	Refer.	Method	Measured Quantity	Environment and Comments
$^{130}_{56}\text{Ba}$	356	63ps	[2]		-1.13 29; -1.10 34 +0.31 <sup>p</sup> 22 or +0.43 <sup>pt</sup> 22	67Si03 72To13	CExRO CExRO	perturbation calc.; 2 level calc. ‡For asymmetric rotor	CEx with $^{16}\text{O}$ , $^{32}\text{S}$ on $^{130}\text{Ba}$ CEx with $^{32}\text{S}$ , $^{40}\text{Ca}$
$^{134}_{56}\text{Ba}$	605	7ps	[2]		-0.46 <sup>p</sup> 11 or -0.70 <sup>p</sup> 11	69Ke16	CExRO		CEx with $^{16}\text{O}$
$^{134}_{56}\text{Ba}$	605	7ps	[2]		+0.16 <sup>p</sup> 28 or +0.21 <sup>pt</sup> 22	72To13	CExRO		CEx with $^{32}\text{S}$ , $^{40}\text{Ca}$
$^{136}_{56}\text{Ba}$	818	1.5ps	[2]		negative, small <sup>p</sup>	69Ke16	CExRO		CEx with $^{16}\text{O}$
$^{136}_{56}\text{Ba}$	818	1.5ps	[2]		+0.34 <sup>p</sup> 52 or +0.43 <sup>pt</sup> 52	72To13	CExRO		CEx with $^{40}\text{Ca}$
$^{142}_{58}\text{Ce}$	650	6.2ps	[2]		-0.12 9	70En01	CExRO		CEx with $^{16}\text{O}$
$^{144}_{60}\text{Nd}$	695	4.2ps	[2]		+0.03 <sup>‡</sup> 21 or -0.07 <sup>‡</sup> 15	70Ge08	CExRO		CEx with He, O, S on thick Nd metal targets
$^{144}_{60}\text{Nd}$	695	4.2ps	[2]		-0.17 or -0.61	71Cr01	CExRO	‡Used $Q_{2+}(^{150}\text{Nd}) = -1.48$ or -2.00 51 $^{144}\text{Nd}_2\text{O}_3$ on C(42MeV $^{16}\text{O}, \text{O}'$ )	
$^{146}_{60}\text{Nd}$	454	21ps	[2]		-0.63 <sup>‡</sup> 10, -0.78 <sup>‡</sup> 9	70Ge08	CExRO		CEx with He, O, S
$^{146}_{60}\text{Nd}$	454	21ps	[2]		-0.72 20	71Cr01	CExRO	‡Used $Q_{2+}(^{150}\text{Nd}) = -1.48$ , -2.00 51 $^{146}\text{Nd}_2\text{O}_3$ on C(42MeV $^{16}\text{O}, \text{O}'$ )	
$^{148}_{60}\text{Nd}$	300	116ps	[2]		-1.24 <sup>‡</sup> 14, -1.46 <sup>‡</sup> 13	70Ge08	CExRO		CEx with He, O, S on Nd metal
$^{148}_{60}\text{Nd}$	300	116ps	[2]		-1.36 30	71Cr01	CExRO	‡For $Q_{2+}(^{150}\text{Nd}) = -1.48$ , -2.00 51 $^{148}\text{Nd}_2\text{O}_3$ on C(42MeV $^{16}\text{O}, \text{O}'$ )	
$^{150}_{60}\text{Nd}$	132	1.52ns	[2]		-1.34 <sup>p</sup> 54	69Ke17	CExRO		CEx with $^4\text{He}$ , $^{16}\text{O}$
$^{150}_{60}\text{Nd}$	132	1.52ns	[2]		-2.00 <sup>‡</sup> 51	70Ge08	CExRO		CEx with He, O, S on Nd
								‡For best fit to Nd data of Crowley and this paper	
$^{148}_{62}\text{Sm}$	551	7ps	[2]		-0.77 34; -0.73 38	67Si03	CExRO	perturbation calc.; 4 level calc.	CEx with $^{16}\text{O}$ , $^{32}\text{S}$ on $^{148}\text{Sm}$
$^{148}_{62}\text{Sm}$	551	7ps	[2]		-0.24 28 or +0.28 28	70Ge07	CExRO		CEx with He, O
$^{148}_{62}\text{Sm}$	551	7ps	[2]		-0.97 <sup>p</sup> 27	72Cl12, 71Cl13	CExRO		CEx with $^4\text{He}$ , $^{16}\text{O}$ , or $^{32}\text{S}$ on thick Sm target; used $Q_{2+}^{152} = -1.653\text{b}$
$^{150}_{62}\text{Sm}$	334	48ps	[2]		-1.28 20; -1.22 22	67Si03	CExRO	perturbation calc.; 4 level calc.	CEx with $^{16}\text{O}$ , $^{32}\text{S}$ on $^{150}\text{Sm}$
$^{150}_{62}\text{Sm}$	334	48ps	[2]		-1.21 <sup>ct</sup>	68Gr03	CExRO	‡Corrections to reorientation by $\beta$ and $\gamma$ bands reduce $Q \sim 10\%$ .	
$^{150}_{62}\text{Sm}$	334	48ps	[2]		-1.31 <sup>p</sup> 19	72Cl12, 71Cl13	CExRO		CEx with $^4\text{He}$ , $^{16}\text{O}$ , $^{32}\text{S}$ ; used $Q_{2+}^{152} = -1.653\text{b}$
$^{152}_{62}\text{Sm}$	122	1.4ns	[2]		-1.8 6	65Go06	CExRO		CEx with $^{16}\text{O}$
$^{152}_{62}\text{Sm}$	122	1.4ns	[2]		-1.65 19	70Ka45	CExRO		CEx with $\sim 23\text{MeV}$ $^{16}\text{O}$
$^{152}_{62}\text{Sm}$	122	1.4ns	[2]		-1.82 <sup>p</sup> 12	71Cl13	CExRO		CEx with $^4\text{He}$ , $^{16}\text{O}$ , $^{32}\text{S}$
$^{166}_{68}\text{Er}$	80.6	1.82ns	[2]		-2.87 95	70Ka45	CExRO		CEx with $\sim 35\text{MeV}$ $^{16}\text{O}$
$^{166}_{68}\text{Er}$	265	120ps	[4]		-2.67 <sup>‡</sup> 90	69Mc20	CExRO		CEx with $^4\text{He}$ , $^{16}\text{O}$
$^{166}_{68}\text{Er}$	787	?	[2]		+2.00 <sup>p</sup> 32	69Mc20	CExRO		CEx with $^4\text{He}$ , $^{16}\text{O}$
$^{168}_{68}\text{Er}$	264	120ps	[4]		-2.2 <sup>p</sup> 10	70Mc27	CExRO		CEx with $^4\text{He}$ , $^{16}\text{O}$ on $^{168}\text{Er}$

**Table K: Nuclear Moments by  
Coulomb Excitation Reorientation and Inelastic Electron-Scattering — Continued**

Nucleus	Level (keV)	$T_{1/2}$	$I$	$\mu$ or $\Omega$	$Q$	Refer.	Method	Measured Quantity	Environment and Comments
$^{170}_{68}\text{Er}$	79	2.0ns	[2]		-1.95 <sup>p</sup> ‡ 26	72Ke22	CExRO		CEx with $^{81}\text{Br}$
								‡No appreciable higher-state corrections needed	
$^{170}_{68}\text{Er}$	261	135ps	[4]		-2.2 <sup>p</sup> 10	70Mc27	CExRO		CEx with $^4\text{He}, ^{16}\text{O}$ on $^{170}\text{Er}$
$^{172}_{70}\text{Yb}$	260	132ps	[4]		-2.3 <sup>p</sup> 12	70Mc27	CExRO		CEx with $^4\text{He}, ^{16}\text{O}$ on $^{172}\text{Yb}$
$^{174}_{70}\text{Yb}$	252	?	[4]		-1.8 <sup>p</sup> 12	70Mc27	CExRO		CEx with $^4\text{He}, ^{16}\text{O}$ on $^{174}\text{Yb}$
$^{176}_{70}\text{Yb}$	270	?	[4]		-0.93 <sup>p</sup> 120	70Mc27	CExRO		CEx with $^4\text{He}, ^{16}\text{O}$ on $^{176}\text{Yb}$
$^{186}_{74}\text{W}$	399	25ps	[4]		-2.6 <sup>p</sup> 13	70Mc27	CExRO		CEx with $^4\text{He}, ^{16}\text{O}$ on $^{186}\text{W}$
$^{186}_{74}\text{W}$	730	4.2ps	[2]		+0.74 42	69Mc20	CExRO		CEx with $^4\text{He}, ^{16}\text{O}$
$^{184}_{76}\text{Os}$	?	?	[2]		-2.4 <sup>p</sup> 11	71La24	CExRO		Relative to $Q_{2+}^{188,190,192}$ (70Pr09)
$^{186}_{76}\text{Os}$	137	840ps	[2]		$\pm 1.47^p 54$	71La24	CExRO		Relative to $Q_{2+}^{188,190,192}$ (70Pr09)
$^{188}_{76}\text{Os}$	155	710ps	[2]		-0.39 38 or -1.31 34	70Pr09	CExRO		CEx with $^4\text{He}, ^{16}\text{O}$
$^{190}_{76}\text{Os}$	187	350ps	[2]		+0.27 12 or -0.99 13	70Pr09	CExRO		CEx with $^4\text{He}, ^{16}\text{O}$
$^{192}_{76}\text{Os}$	206	280ps	[2]		+1.22 19 or -0.41 20	70Pr09	CExRO		CEx with $^4\text{He}, ^{16}\text{O}$
$^{194}_{78}\text{Pt}$	328	35ps	[2]		+0.64 16 or +0.87 18	69Gl08	CExRO		CEx with $^{16}\text{O}, ^1\text{H}$ on $^{194}\text{Pt}$
$^{196}_{78}\text{Pt}$	356	35ps	[2]		+0.51 18 or +0.58 18	69Gl08	CExRO		CEx with $^{16}\text{O}, ^1\text{H}$ on $^{196}\text{Pt}$
$^{198}_{78}\text{Pt}$	408	19ps	[2]		+1.22 50	69Gl08	CExRO		CEx with $^{16}\text{O}, ^1\text{H}$ on $^{198}\text{Pt}$
$^{208}_{82}\text{Pb}$	2615	15ps	[3]		-1.3 6	69Ba51	CExRO		CEx with $^4\text{He}, ^{16}\text{O}$
$^{208}_{82}\text{Pb}$	2615	15ps	[3]		-1.1 <sup>p</sup> ‡ 4 or -0.9 <sup>p</sup> ‡ 4	72Ba88	CExRO	‡For $Q_{2+}^{206} = 0$ or -0.36 b	CEx with $^{12}\text{C}, ^{20}\text{Ne}, ^{32}\text{S}, ^{40}\text{Ar}$ on Pb; measured relative $\gamma$ -yields

\* Polarization or Sternheimer correction included

‡ Recalculation of earlier data

<sup>i</sup> Intrinsic quadrupole moment

<sup>p</sup> Preliminary value from meeting abstract, report, thesis, or private communication

## 6. References

The references are listed here according to their alphanumeric code number. The first two digits represent the year of publication. The two letters that follow are the first two letters of the first surname. Compound surnames, such as those beginning with de, Van, von, zu, are alphabetized by the first two letters of the compound name, e.g. De, Va, Vo, Zu. The digits that follow are merely ordering numbers.

The references before 1960 had originally been

given single letter codes, as they appear in the tables. The Nuclear Data Project reference numbers have all been converted to two letter (six alphanumeric) codes, which keep the same ordering number for numbers below 100. For those above 100, the hundreds digit has been dropped, while 100 becomes 10. Since there are less than 10 references with the same letter for any year before 1960 in our table, it will not be difficult to find the correct reference.

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