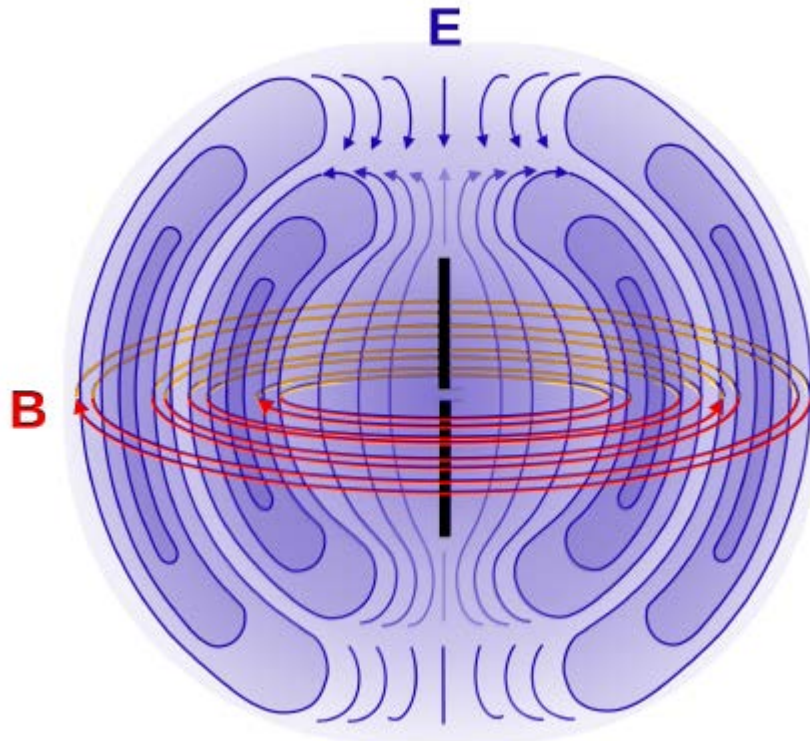


Electric/magnetic dipoles

Electric and magnetic dipole fields have opposite parity:
Magnetic dipoles have even parity and electric dipole fields have odd parity.

$$\Rightarrow \pi(M\ell) = (-1)^{\ell+1} \text{ and } \pi(E\ell) = (-1)^\ell$$



- ❖ The nucleus is a collection of moving charges, which can induce magnetic/electric fields
- ❖ The power radiated into a small area element is proportional to $\sin^2(\theta)$
- ❖ The average power radiated for an **electric dipole** is:

$$P = \frac{1}{12\pi\epsilon_0} \frac{\omega^4}{c^3} d^2$$

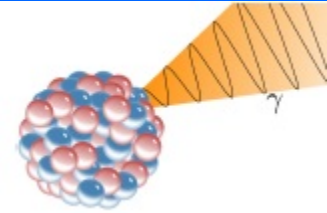
- ❖ For a **magnetic dipole** is

$$P = \frac{1}{12\pi\epsilon_0} \frac{\omega^4}{c^5} \mu^2$$

Higher order multipoles

It is possible to describe the angular distribution of the radiation field as a function of the *multipole order* using Legendre polynomials.

- ℓ : The index of radiation
 2^ℓ : The multipole order of the radiation
- $\ell = 1 \rightarrow \text{Dipole}$
 $\ell = 2 \rightarrow \text{Quadrupole}$
 $\ell = 3 \rightarrow \text{Octupole}$
- The associated Legendre polynomials $P_{2\ell}(\cos(\theta))$ are:
For $\ell = 1$: $P_2 = \frac{1}{2}(3 \cdot \cos^2(\theta) - 1)$
For $\ell = 2$: $P_4 = \frac{1}{8}(35\cos^4(\theta) - 30\cos^2(\theta) + 3)$



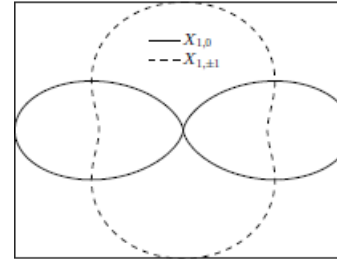
- ❖ *The photon is a spin-1 boson*
- ❖ Like α -decay and β -decay the emitted γ -ray can carry away units of *angular momentum* ℓ , which has given us different multipolarities for transitions.
- ❖ For orbital angular momentum, we can have values $\ell = 0, 1, 2, 3, \dots$ that correspond to our multipolarity.
- ❖ Therefore, our selection rule is:

$$|I_i - I_f| \leq \ell \leq I_i + I_f$$

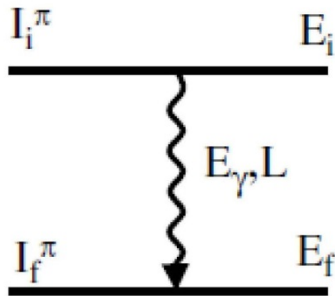
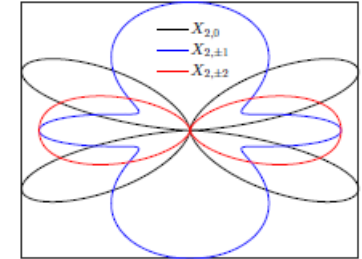
Characteristics of multipolarity selection rules

L	multipolarity	$\pi(E\ell) / \pi(M\ell)$	angular distribution
1	dipole	-1 / +1	
2	quadrupole	+1 / -1	
3	octupole	-1 / +1	
4	hexadecapole	+1 / -1	
⋮			

$\ell = 1$



$\ell = 2$



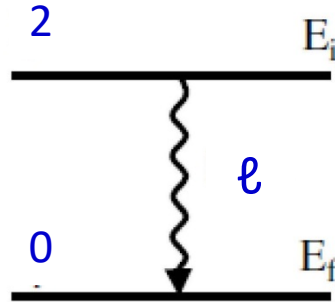
$$E_\gamma = E_i - E_f$$

$$|I_i - I_f| \leq \ell \leq I_i + I_f$$

$$\Delta\pi(E\ell) = (-1)^\ell$$

$$\Delta\pi(M\ell) = (-1)^{\ell+1}$$

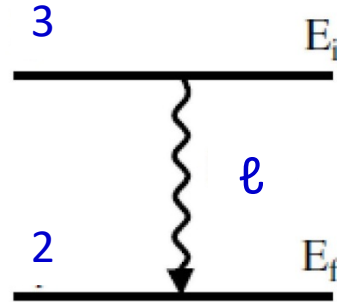
The basics of the situation



$$|2 - 0| \leq \ell \leq 2 + 0$$

Here $\Delta I = 2$ and $\ell = 2$
this is a stretched transition

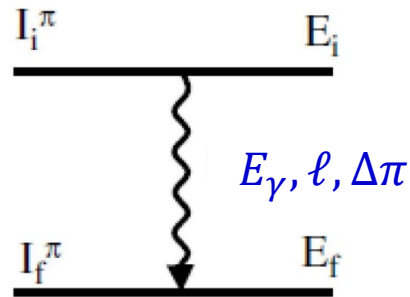
The basics of the situation



$$|3 - 2| \leq \ell \leq 3 + 2$$

Here $\Delta I = 1$ but $\ell = 1, 2, 3, 4, 5$
and the transition can be a mix of 5 multipolarities

The basics of the situation



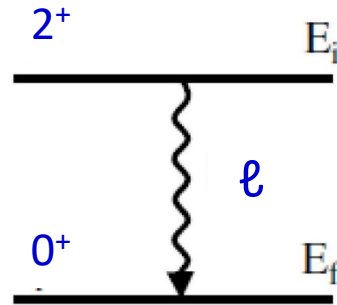
Electromagnetic transitions:

$$\Delta\pi (\text{electric}) = (-1)^\ell$$

$$\Delta\pi (\text{magnetic}) = (-1)^{\ell+1}$$

$\Delta\pi$	yes	E1	M2	E3	M4
	no	M1	E2	M3	E4

The basics of the situation

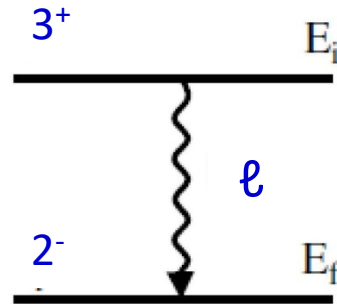


$$|2 - 0| \leq \ell \leq 2 + 0$$

$\ell = 2$ and no change in parity

$\Delta\pi$					
	no	M1	E2	M3	E4

The basics of the situation



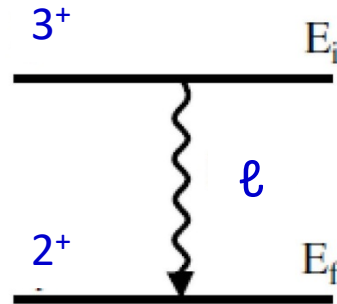
$$|3 - 2| \leq \ell \leq 3 + 2$$

Here $\Delta I = 1$ but $\ell = 1, 2, 3, 4, 5$

$\Delta\pi$	yes	E1	M2	E3	M4

mixed E1, M2, E3, M4, E5

The basics of the situation



$$|3 - 2| \leq \ell \leq 3 + 2$$

Here $\Delta J = 1$ but $\ell = 1, 2, 3, 4, 5$

$\Delta\pi$					
	no	M1	E2	M3	E4

mixed M1,E2,M3,E4,M5

The basics of the situation

$3^+ \rightarrow 2^+$: mixed M1,E2,M3,E4,M5

$3^+ \rightarrow 2^-$: mixed E1,M2,E3,M4,E5

In general only the lowest 2 multipoles compete

and (for reasons we will see later)

$\ell + 1$ multipole generally only competes if it is electric:

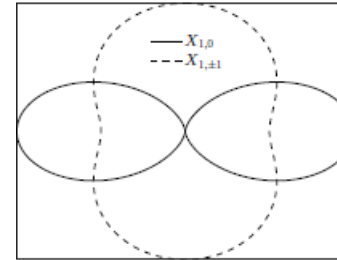
$3^+ \rightarrow 2^+$: mixed M1/E2

$3^+ \rightarrow 2^-$: almost pure E1 (very little M2 admixture)

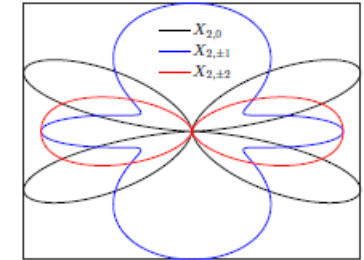
Characteristics of multipolarity

L	multipolarity	$\pi(E\ell) / \pi(M\ell)$	angular distribution
1	dipole	-1 / +1	
2	quadrupole	+1 / -1	
3	octupole	-1 / +1	
4	hexadecapole	+1 / -1	
⋮			

$\ell = 1$



$\ell = 2$



parity: electric multipoles $\pi(E\ell) = (-1)^\ell$, magnetic multipoles $\pi(M\ell) = (-1)^{\ell+1}$

The **power radiated** is proportional to:

$$P(\sigma\ell) \propto \frac{2(\ell+1) \cdot c}{\varepsilon_0 \cdot \ell \cdot [(2\ell+1)!!]^2} \left(\frac{\omega}{c}\right)^{2\ell+2} |\mathcal{M}(\sigma\ell)|^2$$

where σ means either E or M and $\mathcal{M}(\sigma\ell)$ is the E or M multipole moment of the appropriate kind.

Emission of electromagnetic radiation

$$T(E1; I_i \rightarrow I_f) = 1.590 \cdot 10^{17} E_\gamma^3 B(E1; I_i \rightarrow I_f)$$

$$T(E2; I_i \rightarrow I_f) = 1.225 \cdot 10^{13} E_\gamma^5 B(E2; I_i \rightarrow I_f)$$

$$T(E3; I_i \rightarrow I_f) = 5.709 \cdot 10^8 E_\gamma^7 B(E3; I_i \rightarrow I_f)$$

$$T(E4; I_i \rightarrow I_f) = 1.697 \cdot 10^4 E_\gamma^9 B(E4; I_i \rightarrow I_f)$$

$$T(M1; I_i \rightarrow I_f) = 1.758 \cdot 10^{13} E_\gamma^3 B(M1; I_i \rightarrow I_f)$$

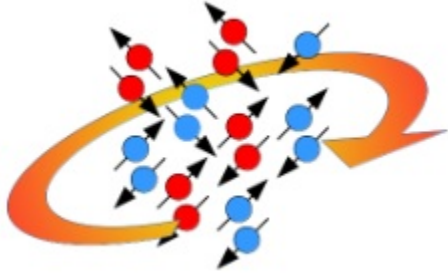
$$T(M2; I_i \rightarrow I_f) = 1.355 \cdot 10^7 E_\gamma^5 B(M2; I_i \rightarrow I_f)$$

$$T(M3; I_i \rightarrow I_f) = 6.313 \cdot 10^0 E_\gamma^7 B(M3; I_i \rightarrow I_f)$$

$$T(M4; I_i \rightarrow I_f) = 1.877 \cdot 10^{-6} E_\gamma^9 B(M4; I_i \rightarrow I_f)$$

where $E_\gamma = E_i - E_f$ is the energy of the emitted γ quantum in MeV (E_i , E_f are the nuclear level energies, respectively), and the reduced transition probabilities $B(E\ell)$ in units of $e^2(\text{barn})^\ell$ and $B(M\ell)$ in units of $\mu_N^2 = (e\hbar/2m_N c)^2 (fm)^{2\ell-2}$

Nuclear shape magnetic moments



- Nuclear magnetic dipole moments arise from
- intrinsic spin magnetic dipole moments of the protons and neutrons
 - circulating currents (motion of the protons)

The **nuclear magnetic dipole moment** can be written as

$$\vec{\mu} = \frac{\mu_N}{\hbar} \sum_i \left[g_L \vec{L} + g_S \vec{S} \right] \quad \text{summed over all } p, n$$

where $\mu_N = e\hbar/2m_p$ is the Nuclear Magneton.

or $\mu = g_J \mu_N J$ where J total nuclear spin quantum number
 g_J nuclear g -factor (analogous to Landé g -factor in atoms)

g_J may be predicted using the Nuclear Shell Model (see later), and measured using magnetic resonance (see Advanced Quantum course).

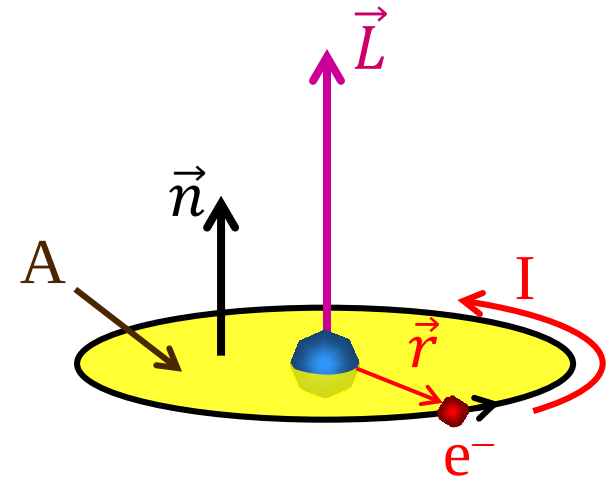
All even-even nuclei have $\mu = 0$ since $J = 0$



Magnetic moment classical description

e^- -movement $\Rightarrow$ magnetic moment $\vec{\mu}_e$

$$\left. \begin{aligned} \vec{\mu}_e &= \frac{I}{c} \cdot A \cdot \vec{n} \\ I &= -e \cdot v = -e \cdot \frac{v}{2\pi r} \\ A &= \pi \cdot r^2 \end{aligned} \right\} \Rightarrow \vec{\mu}_e = -\frac{1}{2} \cdot \frac{e \cdot v \cdot r \cdot \vec{n}}{c}$$



angular momentum: $\vec{L} = \vec{r} \times \vec{p} = r \cdot m_e \cdot v \cdot \vec{n} \Rightarrow \vec{\mu}_e = -\frac{e}{2 \cdot m_e \cdot c} \vec{L}$

Quantum mechanical description: angular momentum will be quantized, in units of $\hbar$.

$$\mu_B = \frac{e \cdot \hbar}{2 \cdot m_e \cdot c} = 5.788 \cdot 10^{-11} \quad \frac{\text{MeV}}{\text{Tesla}}$$

$$\mu_K = \frac{e \cdot \hbar}{2 \cdot m_p \cdot c} = 3.152 \cdot 10^{-14} \quad \frac{\text{MeV}}{\text{Tesla}}$$



Quark model

	<i>Charge</i>	<i>Mass m_q</i>	<i>Spin</i>	<i>mag. Moment</i>
<i>u-quark</i>	+ 2/3	$\sim 1/3 M_p$	1/2	$2 \cdot \left(\frac{2}{3}\right) \cdot \frac{e \cdot \hbar}{2 \cdot m_q \cdot c} \cdot s = 4 \cdot \mu_K \cdot s$
<i>d-quark</i>	- 1/3	$\sim 1/3 M_p$	1/2	$2 \cdot \left(-\frac{1}{3}\right) \cdot \frac{e \cdot \hbar}{2 \cdot m_q \cdot c} \cdot s = -2 \cdot \mu_K \cdot s$

general coupling rule:

$$g(j_1 \times j_2; J) = \frac{1}{2}(g_1 + g_2) + \frac{j_1(j_1 + 1) - j_2(j_2 + 1)}{2 \cdot J \cdot (J + 1)} \cdot (g_1 - g_2)$$

Proton (uud) :

$$g(1/2 \times 1/2; 1) = \frac{1}{2}(4 + 4) + \frac{1/2 \cdot 3/2 - 1/2 \cdot 3/2}{2 \cdot 1 \cdot 2} \cdot (4 - 4) = 4$$

$$g(1 \times 1/2; 1/2) = \frac{1}{2}(4 - 2) + \frac{2 - 3/4}{3/2} \cdot (4 + 2) = \boxed{+6}$$

Neutron (ddu) :

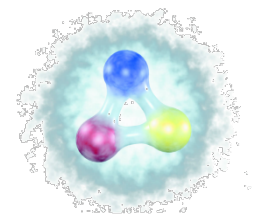
$$g(1/2 \times 1/2; 1) = \frac{1}{2}(-2 - 2) + \frac{1/2 \cdot 3/2 - 1/2 \cdot 3/2}{2 \cdot 1 \cdot 2} \cdot (-2 + 2) = -2$$

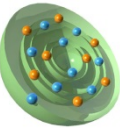
$$g(1 \times 1/2; 1/2) = \frac{1}{2}(-2 + 4) + \frac{2 - 3/4}{3/2} \cdot (-2 - 4) = \boxed{-4}$$

$g_{\text{Dirac}} = 2$ prediction of the Dirac-theory for the gyromagnetic factor for spin $1/2$ -particles

$g_s^{\text{proton}} = +5.58 \Rightarrow$ big deviation from $g = 2 \Leftrightarrow$ no fundamental particle

$g_s^{\text{neutron}} = -3.82$





➤ Magnetic moments:

The g-factor g_j is given by:

$$\vec{\mu}_j = g_\ell \cdot \vec{\ell} + g_s \cdot \vec{s} = g_j \cdot \vec{j}$$

$$\Rightarrow \vec{\mu}_j = \left[(g_\ell \cdot \vec{\ell} + g_s \cdot \vec{s}) \cdot \frac{\vec{j}}{|\vec{j}|} \right] \cdot \frac{\vec{j}}{|\vec{j}|}$$

with $\vec{\ell}^2 = (\vec{j} - \vec{s})^2 = j^2 - 2 \cdot \vec{j} \cdot \vec{s} + s^2$ $\vec{s}^2 = (\vec{j} - \vec{\ell})^2 = j^2 - 2 \cdot \vec{j} \cdot \vec{\ell} + \ell^2$

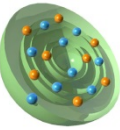
$$\vec{\mu}_j = \frac{g_\ell \cdot \{j(j+1) + \ell(\ell+1) - 3/4\} + g_s \cdot \{j(j+1) - \ell(\ell+1) + 3/4\}}{2 \cdot j(j+1)} \cdot \vec{j}$$

$$g_j = \frac{1}{2} \cdot (g_\ell + g_s) + \frac{1}{2} \cdot \frac{\ell(\ell+1) - s(s+1)}{2j(j+1)} \cdot (g_\ell - g_s)$$

Simple relation for the g-factor
of single-particle states

$$\frac{\mu}{\mu_N} = g_{\text{nucleus}} = g_\ell \pm \frac{(g_s - g_\ell)}{2\ell + 1} \quad \text{for } j = \ell \pm 1$$

nucleus	state	J^π	μ/μ_N model	experiment
^{15}N	$p\text{-}1p_{1/2}^{-1}$	$1/2^-$	-0,264	-0,283
^{15}O	$n\text{-}1p_{1/2}^{-1}$	$1/2^-$	+0,638	+0,719
^{17}O	$n\text{-}1d_{5/2}$	$5/2^+$	-1,913	-1,894
^{17}F	$p\text{-}1d_{5/2}$	$5/2^+$	+4,722	+4,793



➤ *magnetic moments:*

$$\langle \mu_z \rangle = \begin{cases} \left[g_\ell \cdot \left(j - \frac{1}{2} \right) + \frac{1}{2} \cdot g_s \right] \cdot \mu_N & \text{for } j = \ell + 1/2 \\ \frac{j}{j+1} \cdot \left[g_\ell \cdot \left(j + \frac{3}{2} \right) - \frac{1}{2} \cdot g_s \right] \cdot \mu_N & \text{for } j = \ell - 1/2 \end{cases}$$

➤ *g-factor of nucleons:*

proton: $g_\ell = 1$; $g_s = +5.585$

neutron: $g_\ell = 0$; $g_s = -3.82$

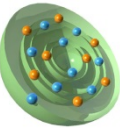
proton:

$$\langle \mu_z \rangle = \begin{cases} (j + 2.293) \cdot \mu_N & \text{for } j = \ell + 1/2 \\ (j - 2.293) \cdot \frac{j}{j+1} \cdot \mu_N & \text{for } j = \ell - 1/2 \end{cases}$$

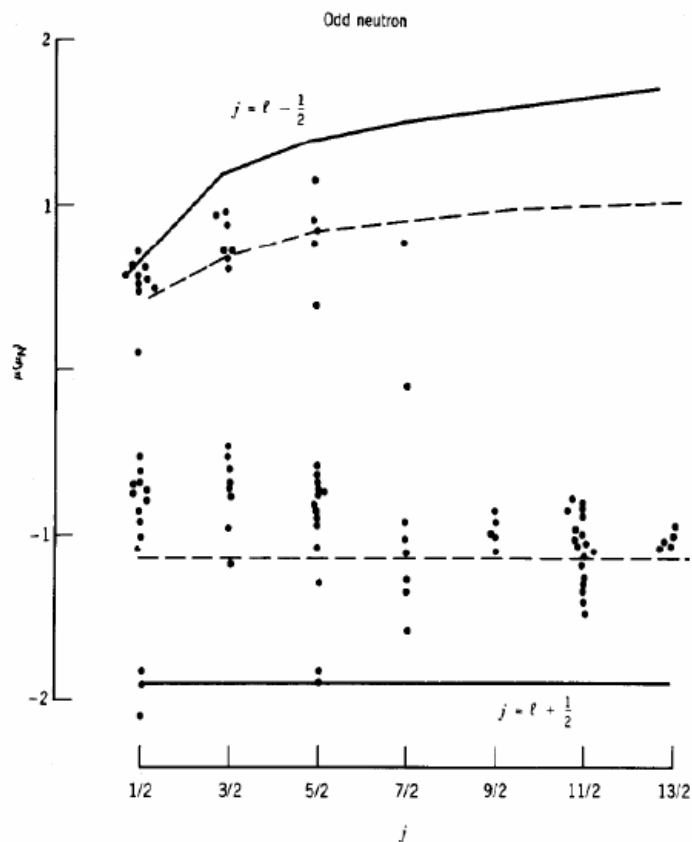
neutron:

$$\langle \mu_z \rangle = \begin{cases} -1.91 \cdot \mu_N & \text{for } j = \ell + 1/2 \\ +1.91 \cdot \frac{j}{j+1} \cdot \mu_N & \text{for } j = \ell - 1/2 \end{cases}$$

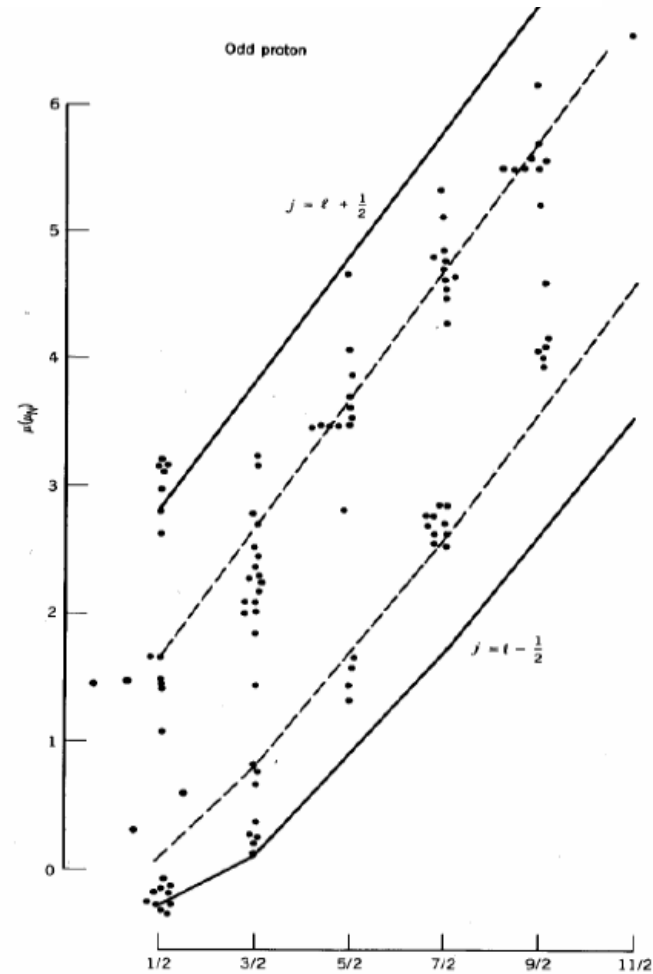
Magnetic moments: Schmidt lines



magnetic moments: **neutron**



magnetic moments: **proton**



Single particle transition (Weisskopf estimate)

$$B(E\lambda; I_i \rightarrow I_{gs}) = \frac{(1.2)^{2\lambda}}{4\pi} \left(\frac{3}{\lambda+3}\right)^2 A^{2\lambda/3} e^2 (fm)^{2\lambda}$$

$$B(M\lambda; I_i \rightarrow I_{gs}) = \frac{10}{\pi} (1.2)^{2\lambda-2} \left(\frac{3}{\lambda+3}\right)^2 A^{(2\lambda-2)/3} \mu_N^2 (fm)^{2\lambda-2}$$

For the first few values of λ , the Weisskopf estimates are

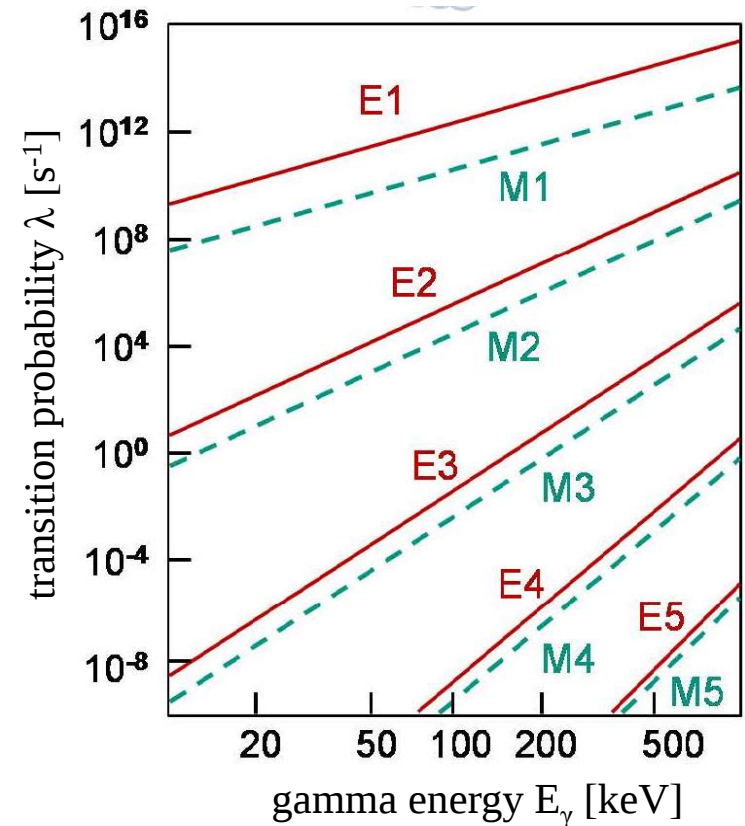
$$B(E1; I_i \rightarrow I_{gs}) = 6.446 \cdot 10^{-4} A^{2/3} e^2 (\text{barn})$$

$$B(E2; I_i \rightarrow I_{gs}) = 5.940 \cdot 10^{-6} A^{4/3} e^2 (\text{barn})^2$$

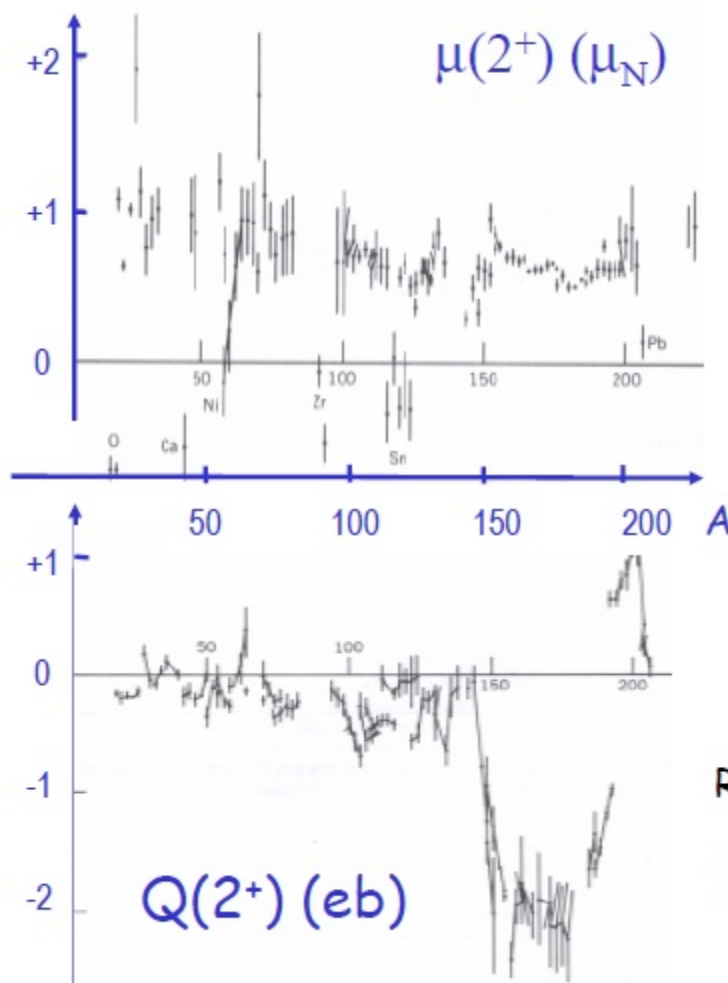
$$B(E3; I_i \rightarrow I_{gs}) = 5.940 \cdot 10^{-8} A^2 e^2 (\text{barn})^3$$

$$B(E4; I_i \rightarrow I_{gs}) = 6.285 \cdot 10^{-10} A^{8/3} e^2 (\text{barn})^4$$

$$B(M1; I_i \rightarrow I_{gs}) = 1.790 \left(\frac{e\hbar}{2Mc}\right)^2$$



Magnetic moments are not sensitive to deformation or collectivity



No signature in the magnetic moments !

Region of well-deformed nuclei
 $A = 150 - 200$
between $Z=50-82$, $N=82-126$
 $|Q| > 1 \text{ eb}$

Odd-even nucleus: ^{181}Ta

72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780	781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840	841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960	961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998	999	1000	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014	1015	1016	1017	1018	1019	1020	1021	1022	1023	1024	1025	1026	1027	1028	1029	1030	1031	1032	1033	1034	1035	1036	1037	1038	1039	1040	1041	1042	1043	1044	1045	1046	1047	1048	1049	1050	1051	1052	1053	1054	1055	1056	1057	1058	1059	1060	1061	1062	1063	1064	1065	1066	1067	1068	1069	1070	1071	1072	1073	1074	1075	1076	1077	1078	1079	1080	1081	1082	1083	1084	1085	1086	1087	1088	1089	1090	1091	1092	1093	1094	1095	1096	1097	1098	1099	1100	1101	1102	1103	1104	1105	1106	1107	1108	1109	1110	1111	1112	1113	1114	1115	1116	1117	1118	1119	1120	1121	1122	1123	1124	1125	1126	1127	1128	1129	1130	1131	1132	1133	1134	1135	1136	1137	1138	1139	1140	1141	1142	1143	1144	1145	1146	1147	1148	1149	1150	1151	1152	1153	1154	1155	1156	1157	1158	1159	1160	1161	1162	1163	1164	1165	1166	1167	1168	1169	1170	1171	1172	1173	1174	1175	1176	1177	1178	1179	1180	1181	1182	1183	1184	1185	1186	1187	1188	1189	1190	1191	1192	1193	1194	1195	1196	1197	1198	1199	1200	1201	1202	1203	1204	1205	1206	1207	1208	1209	1210	1211	1212	1213	1214	1215	1216	1217	1218	1219	1220	1221	1222	1223	1224	1225	1226	1227	1228	1229	1230	1231	1232	1233	1234	1235	1236	1237	1238	1239	1240	1241	1242	1243	1244	1245	1246	1247	1248	1249	1250	1251	1252	1253	1254	1255	1256	1257	1258	1259	1260	1261	1262	1263	1264	1265	1266	1267	1268	1269	1270	1271	1272	1273	1274	1275	1276	1277	1278	1279	1280	1281	1282	1283	1284	1285	1286	1287	1288	1289	1290	1291	1292	1293	1294	1295	1296	1297	1298	1299	1300	1301	1302	1303	1304	1305	1306	1307	1308	1309	1310	1311	1312	1313	1314	1315	1316	1317	1318	1319	1320	1321	1322	1323	1324	1325	1326	1327	1328	1329	1330	1331	1332	1333	1334	1335	1336	1337	1338	1339	1340	1341	1342	1343	1344	1345	1346	1347	1348	1349	1350	1351	1352	1353	1354	1355	1356	1357	1358	1359	1360	1361	1362	1363	1364	1365	1366	1367	1368	1369	1370	1371	1372	1373	1374	1375	1376	1377	1378	1379	1380	1381	1382	1383	1384	1385	1386	1387	1388	1389	1390	1391	1392	1393	1394	1395	1396	1397	1398	1399	1400	1401	1402	1403	1404	1405	1406	1407	1408	1409	1410	1411	1412	1413	1414	1415	1416	1417	1418	1419	1420	1421	1422	1423	1424	1425	1426	1427	1428	1429	1430	1431	1432	1433	1434	1435	1436	1437	1438	1439	1440	1441	1442	1443	1444	1445	1446	1447	1448	1449	1450	1451	1452	1453	1454	1455	1456	1457	1458	1459	1460	1461	1462	1463	1464	1465	1466	1467	1468	1469	1470	1471	1472	1473	1474	1475	1476	1477	1478	1479	1480	1481	1482	1483	1484	1485	1486	1487	1488	1489	1490	1491	1492	1493	1494	1495	1496	1497	1498	1499	1500	1501	1502	1503	1504	1505	1506	1507	1508	1509	1510	1511	1512	1513	1514	1515	1516	1517	1518	1519	1520	1521	1522	1523	1524	1525	1526	1527	1528	1529	1530	1531	1532	1533	1534	1535	1536	1537	1538	1539	1540	1541	1542	1543	1544
----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------

Odd-even nucleus: ^{181}Ta

74	W	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	W187	W188	W189	W190	
	W150	W159	W160	W161	W162	W163	W164	W165	W166	W167	W168	W169	W170	W171	W172	W173	W174	W175	W17															

$$13/2^+ \quad 0.495 \quad \tau = 9.1 \pm 1.2 \text{ ps}$$

$$\tau = \left\{ \sum_K \sum_\ell [\varepsilon_{N \rightarrow K}^2(\lambda) + \delta_{N \rightarrow K}^2(\lambda)] \right\}^{-1}$$

$$11/2^+ \quad 0.302 \quad \tau = 23.1 \pm 4.3 \text{ ps}$$

$$\tau = T_{1/2} / \ln 2$$

$$9/2^+ \quad 0.136 \quad \tau = 57.0 \pm 2.3 \text{ ps}$$

$$7/2^+ \quad 0.0$$

^{181}Ta

$$\delta_{N \rightarrow M}(\lambda) = \left\{ \frac{8\pi(\lambda+1)}{\lambda![(2\lambda+1)!!]^2} \frac{1}{\hbar} \left(\frac{\hbar\omega}{\hbar c} \right)^{2\lambda+1} \right\}^{1/2} \cdot (2I_N + 1)^{-1/2} \cdot \langle I_M \| \mathcal{M}(\lambda) \| I_N \rangle$$

$$\delta_{N \rightarrow M}(E2) = \{1.225 \cdot 10^{13} \cdot E_\gamma^5(\text{MeV})^5\}^{1/2} \cdot (2I_n + 1)^{-1/2} \cdot \langle I_M \| \mathcal{M}(E2) \| I_N \rangle$$

$$\delta_{N \rightarrow M}(M1) = \{1.758 \cdot 10^{13} \cdot E_\gamma^3(\text{MeV})^3\}^{1/2} \cdot (2I_n + 1)^{-1/2} \cdot \langle I_M \| \mathcal{M}(M1) \| I_N \rangle$$

$$\varepsilon_{N \rightarrow M}^2(\ell) = \delta_{N \rightarrow M}^2(\ell) \cdot \alpha_{N \rightarrow M}(\ell)$$

Odd-even nucleus: ^{181}Ta

72	Hf	73	Ta	74	W	75	Re	76	Os	77	Ir	78	Pt	79	Au	80	Hg	81	Tl	82	Pb	83	Bi	84	Po	85	At	86	Rn	87	Fr	88	Ra	89	Ac	90	Th	91	Pa	92	U	93	Np	94	Pu	95	Am	96	Cm	97	Bk	98	Cf	99	Es	100	Fm	101	Mn	102	Sg	103	Bh	104	Hs	105	Ds	106	Lr	107	La	108	Ce	109	Pr	110	Nd	111	Pm	112	Sm	113	Eu	114	Gd	115	Tb	116	Dy	117	Ho	118	Er	119	Tm	120	Yb	121	Lu	122	Hf	123	Ta	124	W	125	Re	126	Os	127	Ir	128	Pt	129	Au	130	Hg	131	Tl	132	Pb	133	Bi	134	Po	135	At	136	Rn	137	Fr	138	Ra	139	Ac	140	Th	141	Pa	142	U	143	Np	144	Pu	145	Am	146	Cm	147	Bk	148	Cf	149	Es	150	Fm	151	Mn	152	Sg	153	Bh	154	Hs	155	Ds	156	Lr	157	La	158	Ce	159	Pr	160	Nd	161	Pm	162	Sm	163	Eu	164	Gd	165	Tb	166	Dy	167	Ho	168	Er	169	Tm	170	Yb	171	Lu	172	Hf	173	Ta	174	W	175	Re	176	Os	177	Ir	178	Pt	179	Au	180	Hg	181	Tl	182	Pb	183	Bi	184	Po	185	At	186	Rn	187	Fr	188	Ra	189	Ac	190	Th	191	Pa	192	U	193	Np	194	Pu	195	Am	196	Cm	197	Bk	198	Cf	199	Es	200	Fm	201	Mn	202	Sg	203	Bh	204	Hs	205	Ds	206	Lr	207	La	208	Ce	209	Pr	210	Nd	211	Pm	212	Sm	213	Eu	214	Gd	215	Tb	216	Dy	217	Ho	218	Er	219	Tm	220	Yb	221	Lu	222	Hf	223	Ta	224	W	225	Re	226	Os	227	Ir	228	Pt	229	Au	230	Hg	231	Tl	232	Pb	233	Bi	234	Po	235	At	236	Rn	237	Fr	238	Ra	239	Ac	240	Th	241	Pa	242	U	243	Np	244	Pu	245	Am	246	Cm	247	Bk	248	Cf	249	Es	250	Fm	251	Mn	252	Sg	253	Bh	254	Hs	255	Ds	256	Lr	257	La	258	Ce	259	Pr	260	Nd	261	Pm	262	Sm	263	Eu	264	Gd	265	Tb	266	Dy	267	Ho	268	Er	269	Tm	270	Yb	271	Lu	272	Hf	273	Ta	274	W	275	Re	276	Os	277	Ir	278	Pt	279	Au	280	Hg	281	Tl	282	Pb	283	Bi	284	Po	285	At	286	Rn	287	Fr	288	Ra	289	Ac	290	Th	291	Pa	292	U	293	Np	294	Pu	295	Am	296	Cm	297	Bk	298	Cf	299	Es	300	Fm	301	Mn	302	Sg	303	Bh	304	Hs	305	Ds	306	Lr	307	La	308	Ce	309	Pr	310	Nd	311	Pm	312	Sm	313	Eu	314	Gd	315	Tb	316	Dy	317	Ho	318	Er	319	Tm	320	Yb	321	Lu	322	Hf	323	Ta	324	W	325	Re	326	Os	327	Ir	328	Pt	329	Au	330	Hg	331	Tl	332	Pb	333	Bi	334	Po	335	At	336	Rn	337	Fr	338	Ra	339	Ac	340	Th	341	Pa	342	U	343	Np	344	Pu	345	Am	346	Cm	347	Bk	348	Cf	349	Es	350	Fm	351	Mn	352	Sg	353	Bh	354	Hs	355	Ds	356	Lr	357	La	358	Ce	359	Pr	360	Nd	361	Pm	362	Sm	363	Eu	364	Gd	365	Tb	366	Dy	367	Ho	368	Er	369	Tm	370	Yb	371	Lu	372	Hf	373	Ta	374	W	375	Re	376	Os	377	Ir	378	Pt	379	Au	380	Hg	381	Tl	382	Pb	383	Bi	384	Po	385	At	386	Rn	387	Fr	388	Ra	389	Ac	390	Th	391	Pa	392	U	393	Np	394	Pu	395	Am	396	Cm	397	Bk	398	Cf	399	Es	400	Fm	401	Mn	402	Sg	403	Bh	404	Hs	405	Ds	406	Lr	407	La	408	Ce	409	Pr	410	Nd	411	Pm	412	Sm	413	Eu	414	Gd	415	Tb	416	Dy	417	Ho	418	Er	419	Tm	420	Yb	421	Lu	422	Hf	423	Ta	424	W	425	Re	426	Os	427	Ir	428	Pt	429	Au	430	Hg	431	Tl	432	Pb	433	Bi	434	Po	435	At	436	Rn	437	Fr	438	Ra	439	Ac	440	Th	441	Pa	442	U	443	Np	444	Pu	445	Am	446	Cm	447	Bk	448	Cf	449	Es	450	Fm	451	Mn	452	Sg	453	Bh	454	Hs	455	Ds	456	Lr	457	La	458	Ce	459	Pr	460	Nd	461	Pm	462	Sm	463	Eu	464	Gd	465	Tb	466	Dy	467	Ho	468	Er	469	Tm	470	Yb	471	Lu	472	Hf	473	Ta	474	W	475	Re	476	Os	477	Ir	478	Pt	479	Au	480	Hg	481	Tl	482	Pb	483	Bi	484	Po	485	At	486	Rn	487	Fr	488	Ra	489	Ac	490	Th	491	Pa	492	U	493	Np	494	Pu	495	Am	496	Cm	497	Bk	498	Cf	499	Es	500	Fm	501	Mn	502	Sg	503	Bh	504	Hs	505	Ds	506	Lr	507	La	508	Ce	509	Pr	510	Nd	511	Pm	512	Sm	513	Eu	514	Gd	515	Tb	516	Dy	517	Ho	518	Er	519	Tm	520	Yb	521	Lu	522	Hf	523	Ta	524	W	525	Re	526	Os	527	Ir	528	Pt	529	Au	530	Hg	531	Tl	532	Pb	533	Bi	534	Po	535	At	536	Rn	537	Fr	538	Ra	539	Ac	540	Th	541	Pa	542	U	543	Np	544	Pu	545	Am	546	Cm	547	Bk	548	Cf	549	Es	550	Fm	551	Mn	552	Sg	553	Bh	554	Hs	555	Ds	556	Lr	557	La	558	Ce	559	Pr	560	Nd	561	Pm	562	Sm	563	Eu	564	Gd	565	Tb	566	Dy	567	Ho	568	Er	569	Tm	570	Yb	571	Lu	572	Hf	573	Ta	574	W	575	Re	576	Os	577	Ir	578	Pt	579	Au	580	Hg	581	Tl	582	Pb	583	Bi	584	Po	585	At	586	Rn	587	Fr	588	Ra	589	Ac	590	Th	591	Pa	592	U	593	Np	594	Pu	595	Am	596	Cm	597	Bk	598	Cf	599	Es	600	Fm	601	Mn	602	Sg	603	Bh	604	Hs	605	Ds	606	Lr	607	La	608	Ce	609	Pr	610	Nd	611	Pm	612	Sm	613	Eu	614	Gd	615	Tb	616	Dy	617	Ho	618	Er	619	Tm	620	Yb	621	Lu	622	Hf	623	Ta	624	W	625	Re	626	Os	627	Ir	628	Pt	629	Au	630	Hg	631	Tl	632	Pb	633	Bi	634	Po	635	At	636	Rn	637	Fr	638	Ra	639	Ac	640	Th	641	Pa	642	U	643	Np	644	Pu	645	Am	646	Cm	647	Bk	648	Cf	649	Es	650	Fm	651	Mn	652	Sg	653	Bh	654	Hs	655	Ds	656	Lr	657	La	658	Ce	659	Pr	660	Nd	661	Pm	662	Sm	663	Eu	664	Gd	665	Tb	666	Dy	667	Ho	668	Er	669	Tm	670	Yb	671	Lu	672	Hf	673	Ta	674	W	675	Re	676	Os	677	Ir	678	Pt	679	Au	680	Hg	681	Tl	682	Pb	683	Bi	684	Po	685	At	686	Rn	687	Fr	688	Ra	689	Ac	690	Th	691	Pa	692	U	693	Np	694	Pu	695	Am	696	Cm	697	Bk	698	Cf	699	Es	700	Fm	701	Mn	702	Sg	703	Bh	704	Hs	705	Ds	706	Lr	707	La	708	Ce	709	Pr	710	Nd	711	Pm	712	Sm	713	Eu	714	Gd	715	Tb	716	Dy	717	Ho	718	Er	719	Tm	720	Yb	721	Lu	722	Hf	723	Ta	724	W	725	Re	726	Os	727	Ir	728	Pt	729	Au	730	Hg	731	Tl	732	Pb	733	Bi	734	Po	735	At	736	Rn	737	Fr	738	Ra	739	Ac	740	Th	741	Pa	742	U	743	Np	744	Pu	745	Am	746	Cm	747	Bk	748	Cf	749	Es	750	Fm	751	Mn	752	Sg	753	Bh	754	Hs	755	Ds	756	Lr	757	La	758	Ce	759	Pr	760	Nd	761	Pm	762	Sm	763	Eu	764	Gd	765	Tb	766	Dy	767	Ho	768	Er	769	Tm	770	Yb	771	Lu	772	Hf	773	Ta	774	W	775	Re	776	Os	777	Ir	778	Pt	779	Au	780	Hg	781	Tl	782	Pb	783	Bi	784	Po	785	At	786	Rn	787	Fr	788	Ra	789	Ac	790	Th	791	Pa	792	U	793	Np	794	Pu	795	Am	796	Cm	797	Bk	798	Cf	799	Es	800	Fm	801	Mn	802	Sg	803	Bh	804	Hs	805	Ds	806	Lr	807	La	808	Ce	809	Pr	810	Nd	811	Pm	812	Sm	813	Eu	814	Gd	815	Tb	816	Dy	817	Ho	818	Er	819	Tm	820	Yb	821	Lu	822	Hf	823	Ta	824	W	825	Re	826	Os	827	Ir	828	Pt	829	Au	830	Hg	831	Tl	832	Pb	833	Bi	834	Po	835	At	836	Rn	837	Fr	838	Ra	839	Ac	840	Th	841	Pa	842	U	843	Np	844	Pu	845	Am	846	Cm	847	Bk	848	Cf	849	Es	850	Fm	851	Mn	852	Sg	853	Bh	854	Hs	855	Ds	856	Lr	857	La	858	Ce	859	Pr	860	Nd	861	Pm	862	Sm	863	Eu	864	Gd	865	Tb	866	Dy	867	Ho	868	Er	869	Tm	870	Yb	871	Lu	872	Hf	873	Ta	874	W	875	Re	876	Os	877	Ir	878	Pt	879	Au	880	Hg	881	Tl	882	Pb	883	Bi	884	Po	885	At	886	Rn	887	Fr	888	Ra	889	Ac	890	Th	891	Pa	892	U	893	Np	894	Pu	895	Am	896	Cm	897	Bk	898	Cf	899	Es	900	Fm	901	Mn	902	Sg	903	Bh	904	Hs	905	Ds	906	Lr	907	La	908	Ce	909	Pr	910	Nd	911	Pm	912	Sm	913	Eu	914	Gd	915	Tb	916	Dy	917	Ho	918	Er	919	Tm	920	Yb	921	Lu	922	Hf	923	Ta	924	W	925	Re	926	Os	927	Ir	928	Pt	929	Au	930	Hg	931	Tl	932	Pb	933	Bi	934	Po	935	At	936	Rn	937	Fr	938	Ra	939	Ac	940	Th	941	Pa	942	U	943	Np	944	Pu	945	Am	946	Cm	947	Bk	948	Cf	949	Es	950	Fm	9
----	----	----	----	----	---	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	---	----	----	----	----	----	----	----	----	----	----	----	----	----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	---	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	-----	----	---

Oddproton-evenneutron nuclei

		μ	$(g_K - g_R)$	$B(M1)W.u.$	$(g_K - g_R)$
^{153}Eu	$5/2^+$	+1.5324(3)	0.551	0.00608(28)	0.185
^{159}Tb	$3/2^+$	+2.014(4)	1.556	0.173(8)	1.471
^{165}Ho	$7/2^-$	+4.177(5)	1.012	0.275(14)	0.973
^{169}Tm	$1/2^+$	-0.2316(15)		0.0342(8)	
^{175}Lu	$7/2^+$	+2.2327(11)	0.298	0.0354(14)	0.349
^{181}Ta	$7/2^+$	+2.3705(7)	0.352	0.068(4)	0.484
^{185}Re	$5/2^+$	+3.1871(3)	1.217	0.28(5)	1.252
^{187}Re	$5/2^+$	+3.2197(3)	1.242	0.260(18)	1.206