

Anhang A

Nuklidmassen und Periodensystem

Die folgenden Tabellen entstammen dem Formelbuch:

- **DCK, DPK, DMK:** *Formeln, Tabellen, Begriffe*, 2. Auflage (Orell Füssli 2010)

Tabelle der stabilen Nuklide (Lebensdauer $\gtrapprox 10^9$ Jahre)

Alle stabilen Isotope nach G. Audi et al. in Nuclear Physics A 729 (2003)

<i>Z</i>	Ordnungszahl
Sy	Chemisches Symbol
<i>A</i>	Nukleonenzahl
rel. H'keit	relative Häufigkeit des Isotops bezogen auf das Isotopengemisch auf der Erde, in % Atome
<i>m_a</i>	atomare Masse in u
<i>M</i>	Molare Masse in 10^{-3} kg/mol

<i>Z</i>	Element	Sy	<i>A</i>	<i>m_a; M</i>	rel. H'keit	<i>Z</i>	Element	Sy	<i>A</i>	<i>m_a; M</i>	rel. H'keit
1	Wasserstoff	H	1	1.007 825 0	99.985	15			15.000 109	0.368	
			2	2.014 101 8	0.015	8	Sauerstoff	O	16	15.994 915	99.757
2	Helium	He	3	3.016 029 3	0.000137				17	16.999 132	0.038
			4	4.002 603 3	99.999863				18	17.999 160	0.205
3	Lithium	Li	6	6.015 122	7.5	9	Fluor	F	19	18.998 403	100
			7	7.016 004	92.5	10	Neon	Ne	20	19.992 440	90.48
4	Beryllium	Be	9	9.012 182	100				21	20.993 847	0.27
5	Bor	B	10	10.012 937	19.9				22	21.991 385	9.25
			11	11.009 305	80.1	11	Natrium	Na	23	22.989 770	100
6	Kohlenstoff	C	12	12 (exakt)	98.93	12	Magnesium	Mg	24	23.985 042	78.99
			13	13.003 355	1.07				25	24.985 837	10.00
7	Stickstoff	N	14	14.003 074	99.632				26	25.982 593	11.01

Z	Element	Sy	A	$m_a; M$	rel. H'keit	Z	Element	Sy	A	$m_a; M$	rel. H'keit
13	Aluminium	Al	27	26.981 538	100				66	65.926 037	27.90
14	Silizium	Si	28	27.976 927	92.230				67	66.927 131	4.10
			29	28.976 495	4.683				68	67.924 848	18.75
			30	29.973 770	3.087				70	69.925 325	0.62
15	Phosphor	P	31	30.973 762	100	31	Gallium	Ga	69	68.925 581	60.108
16	Schwefel	S	32	31.972 071	94.93				71	70.924 705	39.892
			33	32.971 458	0.76	32	Germanium	Ge	70	69.924 250	20.84
			34	33.967 867	4.29				72	71.922 076	27.54
			36	35.967 081	0.02				73	72.923 459	7.73
17	Chlor	Cl	35	34.968 853	75.78				74	73.921 178	36.28
			37	36.965 903	24.22				76	75.921 403	7.61
18	Argon	Ar	36	35.967 546	0.337	33	Arsen	As	75	74.921 596	100
			38	37.962 732	0.063	34	Selen	Se	74	73.922 477	0.89
			40	39.962 383	99.600				76	75.919 214	9.37
19	Kalium	K	39	38.963 707	93.258				77	76.919 915	7.63
			40	39.963 999	0.012				78	77.917 310	23.77
			41	40.961 826	6.730				80	79.916 522	49.61
20	Calcium	Ca	40	39.962 591	96.941	35	Brom	Br	79	78.918 338	50.69
			42	41.958 618	0.647				81	80.916 291	49.31
			43	42.958 767	0.135	36	Krypton	Kr	78	77.920 386	0.35
			44	43.955 481	2.086				80	79.916 378	2.28
			46	45.953 693	0.004				82	81.913 485	11.58
			48	47.952 534	0.187				83	82.914 136	11.49
21	Scandium	Sc	45	44.955 910	100				84	83.911 507	57.00
22	Titan	Ti	46	45.952 629	8.25	37	Rubidium	Rb	85	84.911 789	72.17
			47	46.951 764	7.44				86	85.910 610	17.30
			48	47.947 947	73.72				87	86.909 183	27.83
			49	48.947 871	5.41	38	Strontium	Sr	84	83.913 425	0.56
			50	49.944 792	5.18				86	85.909 262	9.86
23	Vanadium	V	50	49.947 163	0.250				87	86.908 879	7.00
			51	50.943 964	99.750				88	87.905 614	82.58
24	Chrom	Cr	50	49.946 050	4.345	39	Yttrium	Y	89	89.905 848	100
			52	51.940 512	83.789	40	Zirkonium	Zr	90	89.904 702	51.45
			53	52.940 654	9.501				91	90.905 644	11.22
			54	53.938 885	2.365				92	91.905 040	17.15
25	Mangan	Mn	55	54.938 050	100				94	93.906 316	17.38
26	Eisen	Fe	54	53.939 615	5.845				96	95.908 276	2.80
			56	55.934 942	91.754	41	Niob	Nb	93	92.906 378	100
			57	56.935 399	2.119	42	Molybdän	Mo	92	91.906 810	14.84
			58	57.933 280	0.282				94	93.905 088	9.25
27	Kobalt	Co	59	58.933 200	100				95	94.905 841	15.92
28	Nickel	Ni	58	57.935 348	68.077				96	95.904 679	16.68
			60	59.930 791	26.223				97	96.906 021	9.55
			61	60.931 060	1.140				98	97.905 408	24.13
			62	61.928 349	3.635	44	Ruthenium	Ru	100	99.907 477	9.63
			64	63.927 970	0.926				96	95.907 598	5.54
29	Kupfer	Cu	63	62.929 601	69.17				98	97.905 287	1.87
			65	64.927 794	30.83				99	98.905 939	12.76
30	Zink	Zn	64	63.929 147	48.63						

Z	Element	Sy	A	$m_a; M$	rel. H'keit	Z	Element	Sy	A	$m_a; M$	rel. H'keit
			100	99.904 220	12.60				131	130.905 082	21.18
			101	100.905 582	17.06				132	131.904 154	26.89
			102	101.904 350	31.55				134	133.905 395	10.44
			104	103.905 430	18.62				136	135.907 220	8.87
45	Rhodium	Rh	103	102.905 504	100	55	Cäsium	Cs	133	132.905 447	100
46	Palladium	Pd	102	101.905 608	1.02	56	Barium	Ba	130	129.906 310	0.106
			104	103.904 035	11.14				132	131.905 056	0.101
			105	104.905 084	22.33				134	133.904 503	2.417
			106	105.903 483	27.33				135	134.905 683	6.592
			108	107.903 894	26.46				136	135.904 570	7.854
			110	109.905 152	11.72				137	136.905 821	11.232
47	Silber	Ag	107	106.905 093	51.839	57	Lanthan	La	138	137.907 107	0.090
			109	108.904 756	48.161				139	138.906 348	99.910
48	Cadmium	Cd	106	105.906 458	1.25	58	Cer	Ce	136	135.907 144	0.185
			108	107.904 183	0.89				138	137.905 986	0.251
			110	109.903 006	12.49				140	139.905 434	88.450
			111	110.904 182	12.80				142	141.909 240	11.114
			112	111.902 757	24.13	59	Praseodym	Pr	141	140.907 648	100
			113	112.904 401	12.22	60	Neodym	Nd	142	141.907 719	27.2
			114	113.903 358	28.73				143	142.909 810	12.2
			116	115.904 755	7.49				144	143.910 083	23.8
49	Indium	In	113	112.904 061	4.29				145	144.912 569	8.3
			115	114.903 878	95.71				146	145.913 112	17.2
50	Zinn	Sn	112	111.904 821	0.97				148	147.916 889	5.7
			114	113.902 782	0.66				150	149.920 887	5.6
			115	114.903 346	0.34	62	Samarium	Sm	144	143.911 995	3.07
			116	115.901 744	14.54				147	146.914 893	14.99
			117	116.902 954	7.68				148	147.914 818	11.24
			118	117.901 606	24.22				149	148.917 180	13.82
			119	118.903 309	8.59				150	149.917 271	7.38
			120	119.902 197	32.58				152	151.919 728	26.75
			122	121.903 440	4.63				154	153.922 205	22.75
			124	123.905 275	5.79	63	Europium	Eu	151	150.919 846	47.81
51	Antimon	Sb	121	120.903 818	57.21				153	152.921 226	52.19
			123	122.904 216	42.79	64	Gadolinium	Gd	152	151.919 788	0.20
52	Tellur	Te	120	119.904 020	0.09				154	153.920 862	2.18
			122	121.903 047	2.55				155	154.922 619	14.80
			123	122.904 273	0.89				156	155.922 120	20.47
			124	123.902 819	4.74				157	156.923 957	15.65
			125	124.904 425	7.07				158	157.924 101	24.84
			126	125.903 306	18.84				160	159.927 051	21.86
			128	127.904 461	31.74	65	Terbium	Tb	159	158.925 343	100
			130	129.906 223	34.08	66	Dysprosium	Dy	156	155.924 278	0.06
53	Iod	I	127	126.904 468	100				158	157.924 405	0.10
54	Xenon	Xe	124	123.905 896	0.09				160	159.925 194	2.34
			126	125.904 269	0.09				161	160.926 930	18.91
			128	127.903 530	1.92				162	161.926 795	25.51
			129	128.904 779	26.44				163	162.928 728	24.90
			130	129.903 508	4.08						

Z	Element	Sy	A	$m_a; M$	rel. H'keit	Z	Element	Sy	A	$m_a; M$	rel. H'keit	
67	Holmium	Ho	164	163.929 171	28.18			186	185.953 838	1.59		
			165	164.930 319	100			187	186.955 748	1.96		
68	Erbium	Er	162	161.928 775	0.14			188	187.955 836	13.24		
			164	163.929 197	1.61			189	188.958 145	16.15		
			166	165.930 290	33.61			190	189.956 445	26.26		
			167	166.932 045	22.93			192	191.961 479	40.78		
			168	167.932 368	26.78		77	Iridium	Ir	191	190.960 591	37.3
			170	169.935 460	14.93			193	192.962 924	62.7		
69	Thulium	Tm	169	168.934 211	100		78	Platin	Pt	190	189.959 930	0.014
70	Ytterbium	Yb	168	167.933 894	0.13			192	191.961 035	0.782		
			170	169.934 759	3.04			194	193.962 664	32.967		
			171	170.936 322	14.28			195	194.964 774	33.832		
			172	161.936 378	21.83			196	195.964 935	25.242		
			173	172.938 207	16.13			198	197.967 876	7.163		
			174	163.938 858	31.83	79	Gold	Au	197	196.966 552	100	
			176	175.942 568	12.76	80	Quecksilber	Hg	196	195.965 815	0.15	
71	Lutetium	Lu	175	174.940 768	97.41			198	197.966 752	9.97		
			176	175.942 682	2.59			199	198.968 262	16.87		
72	Hafnium	Hf	174	173.940 040	0.16			200	199.968 309	23.10		
			176	175.941 402	5.26			201	200.970 285	13.18		
			177	176.943 220	18.60			202	201.970 626	29.86		
			178	177.943 698	27.28			204	203.973 476	6.87		
			179	178.945 815	13.62	81	Thallium	Tl	203	202.972 329	29.524	
			180	179.946 549	35.08			205	204.974 412	70.476		
73	Tantal	Ta	180	179.947 466	0.012		82	Blei	Pb	204	203.973 029	1.4
			181	180.947 996	99.988			206	205.974 449	24.1		
74	Wolfram	W	180	179.946 706	0.12			207	206.975 881	22.1		
			182	181.948 206	26.50			208	207.976 636	52.4		
			183	182.950 224	14.31	83	Bismut	Bi	209	208.980 383	100	
			184	183.950 933	30.64	90	Thorium	Th	232	232.038 050	100	
			186	185.954 362	28.43	92	Uran	U	234	234.040 946	0.005	
75	Rhenium	Re	185	184.952 956	37.40			235	235.043 923	0.720		
			187	186.955 751	62.60			238	238.050 783	99.275		
76	Osmium	Os	184	183.952 491	0.02							

Auswahl radioaktiver Nuklide

m_a Atommasse in u

$T_{1/2}$ Halbwertszeit (a = Jahr, d = Tag, h = Stunde, min = Minute, s = Sekunde)

Zerfallsart ε Elektroneneinfang; \bullet Zerfall *nicht* von γ -Strahlung begleitet

Energien bei β -Energien immer Maximalwerte; Zerfallsanteile < 2% weggelassen

Nuklid	$m_a; M$	$T_{1/2}$	Zerfallsart	Energien (MeV)
n	1.008 664 915 7	613.9	s	$\beta^- \bullet$ 0.7824
H-3	3.016 049	12.32	a	$\beta^- \bullet$ 0.0186
Be-10	10.013 534	$1.51 \cdot 10^6$	a	$\beta^- \bullet$ 0.5558
C-14	14.003 242	$5.70 \cdot 10^3$	a	$\beta^- \bullet$ 0.1565
Na-22	21.994 436	2.6019	a	$\beta^+ \varepsilon \bullet$ β^+ : 0.545 / γ : 1.275
Na-24	23.990 963	14.9590	h	$\beta^- \gamma$ β^- : 1.393 / γ : 1.369; 2.754
P-32	31.973 907	14.263	d	$\beta^- \bullet$ 1.710

Ar-41	40.964 501	109.61	min	$\beta^- \gamma$	β^- : 1.198 / γ : 1.293 (99%)
K-40	39.963 998	$1.261 \cdot 10^9$	a	$\beta^+ \varepsilon \beta^- \gamma$	β^- : 1.311 / γ : 1.460 (11%)
Fe-55	54.938 293	2.737	a	ε	
Co-60	59.933 817	5.2713	a	$\beta^- \gamma$	β^- : 0.318 / γ : 1.173; 1.332
Kr-85	84.912 527	10.776	a	$\beta^- \gamma$	β^- : 0.687
Rb-87	86.909 181	$4.923 \cdot 10^{10}$	a	$\beta^- \bullet$	0.283
Sr-89	88.907 451	50.53	d	$\beta^- \gamma$	β^- : 1.495
Sr-90	89.907 738	28.79	a	$\beta^- \bullet$	0.546
Tc-99 m	98.906 255	6.015	h	γ	0.140 (90%)
Ag-108	107.905 956	2.37	min	$\beta^+ \varepsilon \beta^-$	β^- : 1.649
Ag-110	109.906 107	24.6	s	$\beta^- \gamma$	β^- : 2.89 / γ : 0.658 (4.5%)
I-128	127.905 809	24.99	min	$\beta^+ \varepsilon \beta^- \gamma$	β^- : 2.12 / γ : 0.443 (13%)
I-131	130.906 125	8.02070	d	$\beta^- \gamma$	β^- : 0.606 / γ : 0.364 (82%); komplex
Xe-135	134.907 227	9.14	h	$\beta^- \gamma$	β^- : 0.90 / γ : 0.250 (90%); 0.608 (3%)
Cs-137	136.907 090	30.1671	a	$\beta^- \gamma$	β^- : 1.176 (6%); 0.514 (94%) / γ : 0.662
Au-198	197.968 242	2.69517	d	$\beta^- \gamma$	β^- : 0.961 / γ : 0.412 (96%) (85%)
Pb-210	209.984 189	22.20	a	$\alpha \varepsilon \gamma$	β^- : 0.064 / γ : 0.047 (4%)
Bi-208	207.979 742	$3.68 \cdot 10^5$	a	$\varepsilon \gamma$	γ : 2.614
Bi-210	209.984 120	5.012	d	$\alpha \beta^-$	β^- : 1.162
Po-210	209.982 874	138.376	d	$\alpha \gamma$	α : 5.304
Rn-220	220.011 394	55.6	s	$\alpha \gamma$	α : 6.29
Rn-222	222.017 578	3.8235	d	$\alpha \gamma$	α : 5.49
Ra-226	226.025 410	$1.600 \cdot 10^3$	a	$\alpha \gamma$	α : 4.78 (94%); 4.60 (6%) / γ : komplex
Ac-227	227.027 752	21.772	a	$\alpha \beta^- \gamma$	β^- : 0.045
Th-230	230.033 134	$7.538 \cdot 10^4$	a	$\alpha \gamma$	α : 4.69 (76%); 4.62 (24%)
Th-232	232.038 055	$1.405 \cdot 10^{10}$	a	$\alpha \gamma$	α : 4.01 (78%); 3.95 (22%)
Pa-231	231.035 884	$3.276 \cdot 10^4$	a	$\alpha \gamma$	α : 5.0 (80%); 4.73 (8%) / γ : komplex
U-233	233.039 635	$1.592 \cdot 10^5$	a	$\alpha \gamma$	α : 4.82 (84%); 4.78 (13%) / γ : komplex
U-234	234.040 952	$2.455 \cdot 10^5$	a	$\alpha \gamma$	α : 4.77 (71%); 4.72 (28%) / γ : komplex
U-235	235.043 930	$7.04 \cdot 10^8$	a	$\alpha \gamma$	α : 4.58 (9%); 4.4 (75%) / γ : komplex
U-238	238.050 788	$4.468 \cdot 10^9$	a	$\alpha \gamma$	α : 4.20 (79%); 4.15 (21%)
U-239	239.054 293	23.45	min	$\beta^- \gamma$	β^- : 1.19 / γ : 0.044 (4%); 0.075 (49%)
Np-239	239.052 939	2.356	d	$\beta^- \gamma$	β^- : 0.330 (42%); 0.436 (45%) / γ : komplex
Pu-239	239.052 163	$2.411 \cdot 10^4$	a	$\alpha \gamma$	α : 5.16 (71%); 5.14 (17%) / γ : komplex
Am-241	241.056 829	432.2	a	$\alpha \gamma$	α : 5.49 (85%); 5.44 (13%) / γ : komplex

Einige Fusionsreaktionen

${}_1^1\text{H}$	+	${}_1^1\text{H}$	\longrightarrow	${}_2^2\text{H}$	+	e^+	(+ 1.44 MeV)
${}_1^1\text{H}$	+	${}_1^2\text{H}$	\longrightarrow	${}_2^3\text{He}$			(+ 5.49 MeV)
${}_1^1\text{H}$	+	${}_3^7\text{Li}$	\longrightarrow	${}_2^4\text{He}$	+	${}_2^4\text{He}$	(+ 17.3 MeV)
${}_1^2\text{H}$	+	${}_1^2\text{H}$	\longrightarrow	${}_2^3\text{He}$	+	n	(+ 3.25 MeV)
${}_1^2\text{H}$	+	${}_1^2\text{H}$	\longrightarrow	${}_1^3\text{H}$	+	${}_1^1\text{H}$	(+ 4.0 MeV)
${}_1^2\text{H}$	+	${}_1^3\text{H}$	\longrightarrow	${}_2^4\text{He}$	+	n	(+ 17.6 MeV)
${}_1^2\text{H}$	+	${}_2^3\text{He}$	\longrightarrow	${}_2^4\text{He}$	+	${}_1^1\text{H}$	(+ 18.3 MeV)
${}_1^2\text{H}$	+	${}_3^6\text{Li}$	\longrightarrow	${}_2^4\text{He}$	+	${}_2^4\text{He}$	(+ 22.4 MeV)
${}_2^3\text{He}$	+	${}_2^3\text{He}$	\longrightarrow	${}_2^4\text{He}$	+	${}_1^1\text{H}$	(+ 12.9 MeV)
${}_1^3\text{H}$	+	${}_1^3\text{H}$	\longrightarrow	${}_2^4\text{He}$	+	n	(+ 11.3 MeV)

Periodensystem der Elemente

Gruppe	IA		II A		III A												IV A		V A		VI A		VII A		VIII A								
	1	2	1	2	H												1	2	1	2	1	2	1	2									
	³ Li 6.941	⁴ Be 9.012																															
	¹¹ Na 22.990	¹² Mg 24.305																															
	19	20	²¹ Sc 44.956		²² Ti 47.867	²³ V 50.942	²⁴ Cr 51.996	²⁵ Mn 54.938	²⁶ Fe 55.845	²⁷ Co 58.933	²⁸ Ni 58.693	²⁹ Cu 63.546	³⁰ Zn 65.39	³¹ Ge 69.723	³² As 72.61	³³ Br 74.922	³⁴ Se 78.96	³⁵ He 79.904															
	39	39	⁴⁰ Ca 40.078	⁴¹ Sc 44.956	⁴⁰ Ti 47.867	⁴¹ V 50.942	⁴² Cr 51.996	⁴³ Mn 54.938	⁴⁴ Fe 55.845	⁴⁵ Co 58.933	⁴⁶ Ni 58.693	⁴⁷ Cu 63.546	⁴⁸ Zn 65.39	⁴⁹ Ge 69.723	⁵⁰ As 72.61	⁵¹ Br 74.922	⁵² Se 78.96	⁵³ He 79.904															
	37	38	³⁹ Sr 87.62	⁴⁰ Y 88.906	⁴¹ Zr 91.224	⁴² Nb 92.906	⁴³ Mo 95.94	⁴⁴ Tc [98]	⁴⁵ Ru 101.07	⁴⁶ Pd 102.906	⁴⁷ Ag 106.42	⁴⁸ Rh 107.868	⁴⁹ Pd 112.41	⁵⁰ Ag 114.818	⁵¹ In 118.710	⁵² Sn 121.76	⁵³ Ge 127.60	⁵⁴ Te 126.904	⁵⁵ Br 131.29														
	55	56	⁵⁷ Ba 137.327	⁵⁸ La 138.906	⁵⁹ La 71	⁶⁰ Hf 178.49	⁶¹ Ta 180.948	⁶² W 183.84	⁶³ Re 186.207	⁶⁴ Os 190.23	⁶⁵ Ir 192.217	⁶⁶ Pt 195.078	⁶⁷ Pt 196.967	⁶⁸ Au 200.59	⁶⁹ Hg 204.383	⁷⁰ Pb 207.2	⁷¹ Bi 208.980	⁷² At 209	⁷³ Rn [210]	⁷⁴ At [222]													
	87	88	⁸⁹ Ra [226]	⁹⁰ Ac [227]	⁹¹ Ra [226]	⁹² Db [261]	⁹³ Rf [262]	⁹⁴ Db [262]	⁹⁵ Db [263]	⁹⁶ Bh [262]	⁹⁷ Hs [262]	⁹⁸ Mt [266]	⁹⁹ Ds [265]	¹⁰⁰ Ds [271]	¹⁰¹ Rg [272]	¹⁰² ut [277]	¹⁰³ ut [284]	¹⁰⁴ ut [289]	¹⁰⁵ ut [288]	¹⁰⁶ ut [289]	¹⁰⁷ ut [289]	¹⁰⁸ ut [289]	¹⁰⁹ ut [289]	¹¹⁰ ut [289]	¹¹¹ ut [289]	¹¹² ut [289]	¹¹³ ut [289]	¹¹⁴ ut [289]	¹¹⁵ ut [289]	¹¹⁶ uuq [289]	¹¹⁷ uuq [289]	¹¹⁸ uuq [289]	¹¹⁹ uuq [289]

⁵⁸ Ce 140.116	⁵⁹ Pr 140.908	⁶⁰ Nd 144.24	⁶¹ Pm 145]	⁶² Sm 150.36	⁶³ Eu 151.964	⁶⁴ Gd 155.25	⁶⁵ Tb 158.925	⁶⁶ Dy 162.50	⁶⁷ Ho 164.930	⁶⁸ Er 167.26	⁶⁹ Tm 168.934	⁷⁰ Yb 173.04	⁷¹ Lu 174.967
⁹⁰ Th 232.038	⁹¹ Pa 231.036	⁹² U 238.029	⁹³ Np [237]	⁹⁴ Pu [244]	⁹⁵ Am [243]	⁹⁶ Cm [247]	⁹⁷ Bk [247]	⁹⁸ Cf [251]	⁹⁹ Es [252]	¹⁰⁰ Fm [257]	¹⁰¹ Md [258]	¹⁰² No [259]	¹⁰³ Lr [262]

In Klammern: Nukleonenanzahl des Isotops mit der längsten Halbwertszeit.