

# Los Alamos National Laboratory Chemistry Division

## Periodic Table of the Elements

1A	2A	3A	4A	5A	6A	7A	8A
1 <b>H</b> hydrogen 1.008	4 <b>Be</b> beryllium 9.012	13 <b>Al</b> aluminum 26.98	14 <b>Si</b> silicon 28.09	15 <b>P</b> phosphorus 30.97	16 <b>S</b> sulfur 32.07	17 <b>Cl</b> chlorine 35.45	18 <b>Ar</b> argon 39.95
2A	3A	4A	5A	6A	7A	8A	
3 <b>Li</b> lithium 6.941	5 <b>B</b> boron 10.81	6 <b>C</b> carbon 12.01	7 <b>N</b> nitrogen 14.01	8 <b>O</b> oxygen 16.00	9 <b>F</b> fluorine 19.00	10 <b>Ne</b> neon 20.18	
3S	3B	4B	5B	6B	7B	8B	9B
11 <b>Na</b> sodium 22.99	21 <b>Sc</b> scandium 44.96	22 <b>Ti</b> titanium 47.88	23 <b>V</b> vanadium 50.94	24 <b>Cr</b> chromium 52.00	25 <b>Mn</b> manganese 54.94	26 <b>Fe</b> iron 55.85	27 <b>Co</b> cobalt 58.93
4S	4B	5B	6B	7B	8B	9B	10B
19 <b>K</b> potassium 39.10	39 <b>Y</b> yttrium 88.91	40 <b>Zr</b> zirconium 91.22	41 <b>Nb</b> niobium 92.91	42 <b>Mo</b> molybdenum 95.94	43 <b>Tc</b> technetium (98)	44 <b>Ru</b> ruthenium 101.1	45 <b>Rh</b> rhodium 102.9
5S	5B	6B	7B	8B	9B	10B	11B
37 <b>Rb</b> rubidium 85.47	57 <b>La*</b> lanthanum 138.9	72 <b>Hf</b> hafnium 178.5	73 <b>Ta</b> tantalum 180.9	74 <b>W</b> tungsten 183.9	75 <b>Re</b> rhenium 186.2	76 <b>Os</b> osmium 190.2	77 <b>Ir</b> iridium 192.2
6S	6B	7B	8B	9B	10B	11B	12B
55 <b>Cs</b> cesium 132.9	88 <b>Ra</b> radium (226)	104 <b>Rf</b> rutherfordium (261)	105 <b>Db</b> dubnium (262)	106 <b>Sg</b> seaborgium (263)	107 <b>Bh</b> bohrium (264)	108 <b>Hs</b> hassium (265)	109 <b>Mt</b> meitnerium (266)
7S	7B	8B	9B	10B	11B	12B	13B
87 <b>Fr</b> francium (223)	89 <b>Ac~</b> actinium (227)	110 <b>Ds</b> darmstadtium (271)	111 <b>Rg</b> roentgenium (272)	112 <b>Cn</b> copernicium (277)	113 <b>Nh</b> nihonium (284)	114 <b>Pb</b> lead 207.2	115 <b>Bi</b> bismuth 208.9

Lanthanide Series\*  
58-71

Actinide Series~  
89-103

58 <b>Ce</b> cerium 140.1	59 <b>Pr</b> praseodymium 140.9	60 <b>Nd</b> neodymium 144.2	61 <b>Pm</b> promethium (147)	62 <b>Sm</b> samarium (150.4)	63 <b>Eu</b> europium 152.0	64 <b>Gd</b> gadolinium 157.3	65 <b>Tb</b> terbium 158.9	66 <b>Dy</b> dysprosium 162.5	67 <b>Ho</b> holmium 164.9	68 <b>Er</b> erbium 167.3	69 <b>Tm</b> thulium 168.9	70 <b>Yb</b> ytterbium 173.0	71 <b>Lu</b> lutetium 175.0
90 <b>Th</b> thorium 232.0	91 <b>Pa</b> protactinium (231)	92 <b>U</b> uranium (238)	93 <b>Np</b> neptunium (237)	94 <b>Pu</b> plutonium (242)	95 <b>Am</b> americium (243)	96 <b>Cm</b> curium (247)	97 <b>Bk</b> berkelium (247)	98 <b>Cf</b> californium (249)	99 <b>Es</b> einsteinium (254)	100 <b>Fm</b> fermium (253)	101 <b>Md</b> mendelevium (258)	102 <b>No</b> nobelium (259)	103 <b>Lr</b> lawrencium (260)

element names in **bold** are liquids at room temperature  
 element names in **red** are gases at room temperature  
 element names in **black** are solids at room temperature

**CHEMISTRY**

**Los Alamos**  
NATIONAL LABORATORY

(A)

[http://en.wikipedia.org/wiki/Island\\_of\\_stability#Half-lives\\_of\\_large\\_isotopes](http://en.wikipedia.org/wiki/Island_of_stability#Half-lives_of_large_isotopes)

Number	Name	Longest-lived measured isotope	Half-life	Article
100	Fermium	<sup>257</sup> Fm	101 days	Isotopes of fermium
101	Mendelevium	<sup>258</sup> Md	52 days	Isotopes of mendelevium
102	Nobelium	<sup>259</sup> No	58 minutes	Isotopes of nobelium
103	Lawrencium	<sup>262</sup> Lr	3.6 hours	Isotopes of lawrencium
104	Rutherfordium	<sup>267</sup> Rf	1.3 hours	Isotopes of rutherfordium
105	Dubnium	<sup>268</sup> Db	29 hours	Isotopes of dubnium
106	Seaborgium	<sup>271</sup> Sg	1.9 minutes	Isotopes of seaborgium
107	Bohrium	<sup>270</sup> Bh	61 seconds	Isotopes of bohrium
108	Hassium	<sup>277</sup> Hs	16.5 minutes	Isotopes of hassium
109	Meitnerium	<sup>278</sup> Mt	~8 seconds	Isotopes of meitnerium
110	Darmstadtium	<sup>281</sup> Ds	11 seconds	Isotopes of darmstadtium
111	Roentgenium	<sup>281</sup> Rg	22.8 seconds	Isotopes of roentgenium
112	Copernicium	<sup>285</sup> Cn	29 seconds	Isotopes of copernicium
113		<sup>286</sup> <sub>113</sub>	19.6 seconds	Isotopes
114	<i>Flerovium</i>	<sup>289</sup> <i>Fl</i>	2.6 seconds	Isotopes
115		<sup>289</sup> <sub>115</sub>	220 ms	Isotopes
116	<i>Livermorium</i>	<sup>293</sup> <i>Lv</i>	61 ms	Isotopes
117		<sup>294</sup> <sub>117</sub>	78 ms	Isotopes
118		<sup>294</sup> <sub>118</sub>	0.89 ms	Isotopes

# Fundamentals In Nuclear Physics

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6 Introduction

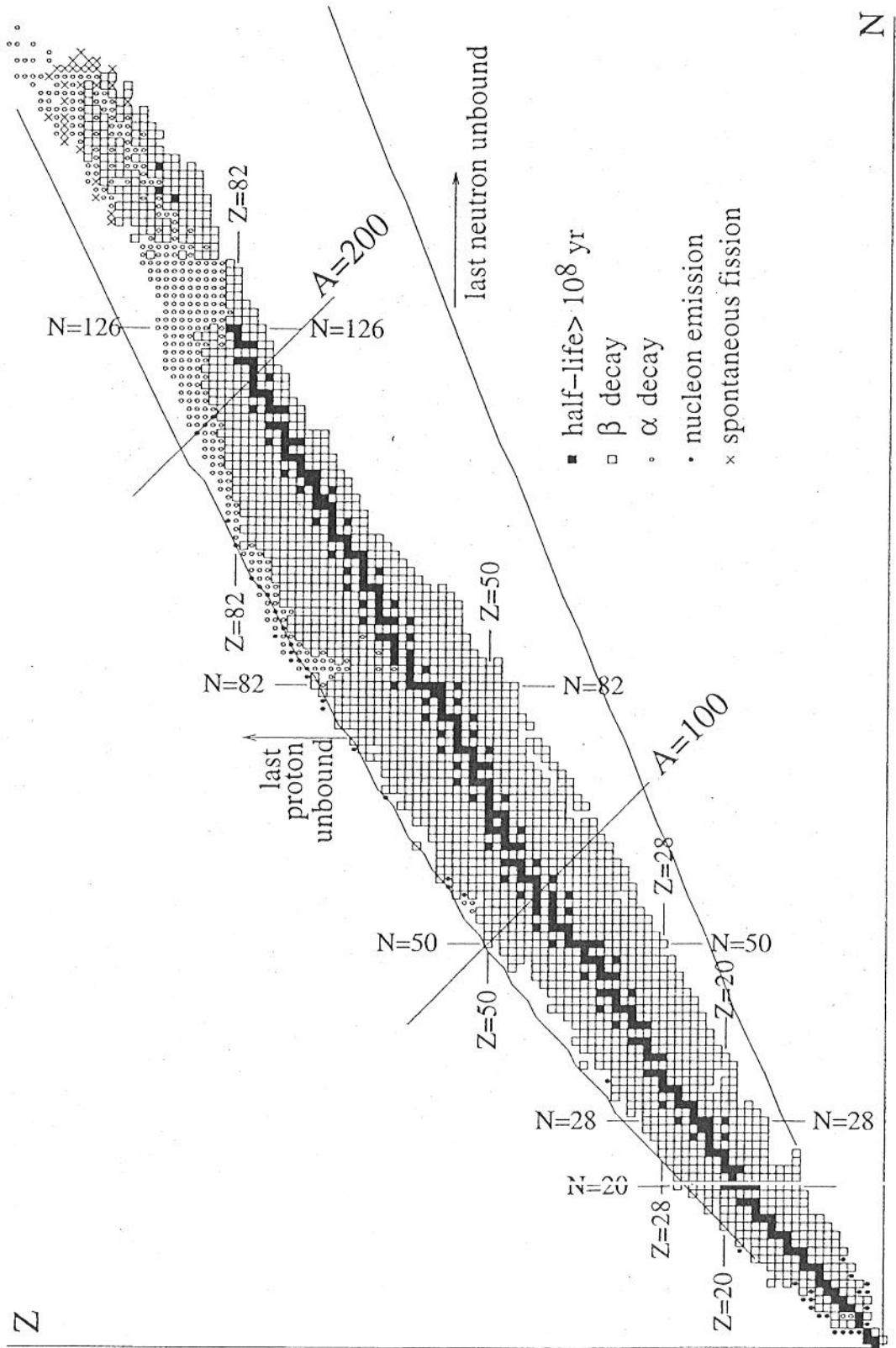


Fig. 0.2. The nuclei. The black squares are long-lived nuclei present on Earth. Unbound combinations of  $(N, Z)$  lie outside the lines marked "last proton/neutron unbound." Most other nuclei  $\beta$ -decay or  $\alpha$ -decay to long-lived nuclei.

## Formulas and Constants

### Particle Data

Mass in  $\text{MeV}/c^2$ , lifetime in seconds, charge in units of the proton charge.

#### Leptons (spin 1/2)

Generation	Flavor	Charge	Mass*	Lifetime	Principal Decays
first	$e$ (electron)	-1	0.510999	$\infty$	-
	$\nu_e$ ( $e$ neutrino)	0	0	$\infty$	-
second	$\mu$ (muon)	-1	105.659	$2.19703 \times 10^{-6}$	$e\nu_\mu\bar{\nu}_e$
	$\nu_\mu$ ( $\mu$ neutrino)	0	0	$\infty$	-
third	$\tau$ (tau)	-1	1776.99	$2.91 \times 10^{-13}$	$e\nu_\tau\bar{\nu}_e, \mu\nu_\tau\bar{\nu}_\mu, \pi^- \nu_\tau$
	$\nu_\tau$ ( $\tau$ neutrino)	0	0	$\infty$	-

\*Neutrino masses are extremely small, and for most purposes can be taken to be zero; for details see Chapter 11.

#### Quarks (spin 1/2)

Generation	Flavor	Charge	Mass*
first	$d$ (down)	-1/3	7
	$u$ (up)	2/3	3
second	$s$ (strange)	-1/3	120
	$c$ (charm)	2/3	1200
third	$b$ (bottom)	-1/3	4300
	$t$ (top)	2/3	174000

\*Light quark masses are imprecise and speculative; for effective masses in mesons and baryons, see Chapter 5.

#### Mediators (spin 1)

Force	Mediator	Charge	Mass*	Lifetime	Principal Decays
Strong	$g$ (8 gluons)	0	0	$\infty$	-
Electromagnetic	$\gamma$ (photon)	0	0	$\infty$	-
Weak	$W^\pm$ (charged)	$\pm 1$	80,420	$3.11 \times 10^{-25}$	$e^+ \nu_e, \mu^+ \nu_\mu, \tau^+ \nu_\tau, cX \rightarrow \text{hadrons}$
	$Z^0$ (neutral)	0	91,190	$2.64 \times 10^{-25}$	$e^+ e^-, \mu^+ \mu^-, \tau^+ \tau^-, q\bar{q} \rightarrow \text{hadrons}$

## Baryons (spin 1/2)

Baryon	Quark Content	Charge	Mass	Lifetime	Principal Decays
N	p	1	938.272	$\infty$	—
	n	0	939.565	885.7	$p\bar{\nu}_e$
$\Lambda$	uds	0	1115.68	$2.63 \times 10^{-10}$	$p\pi^-, n\pi^0$
$\Sigma^+$	uus	1	1189.37	$8.02 \times 10^{-11}$	$p\pi^0, n\pi^+$
$\Sigma^0$	uds	0	1192.64	$7.4 \times 10^{-20}$	$\Lambda\gamma$
$\Sigma^-$	dds	-1	1197.45	$1.48 \times 10^{-10}$	$n\pi^-$
$\Xi^0$	uss	0	1314.8	$2.90 \times 10^{-10}$	$\Lambda\pi^0$
$\Xi^-$	dss	-1	1321.3	$1.64 \times 10^{-10}$	$\Lambda\pi^-$
$\Lambda_c^+$	udc	1	2286.5	$2.00 \times 10^{-13}$	$pK\pi, \Lambda\pi\pi, \Sigma\pi\pi$

## Baryons (spin 3/2)

Baryon	Quark Content	Charge	Mass	Lifetime	Principal Decays
$\Delta$	uuu, uud, udd, ddd	2, 1, 0, -1	1232	$5.6 \times 10^{-24}$	$N\pi$
$\Sigma^*$	uus, uds, dds	1, 0, -1	1385	$1.8 \times 10^{-23}$	$\Lambda\pi, \Sigma\pi$
$\Xi^*$	uss, dss	0, -1	1533	$6.9 \times 10^{-23}$	$\Xi\pi$
$\Omega^-$	sss	-1	1672	$8.2 \times 10^{-11}$	$\Lambda K^-, \Xi\pi$

## Pseudoscalar Mesons (spin 0)

Meson	Quark Content	Charge	Mass	Lifetime	Principal Decays
$\pi^\pm$	ud, d $\bar{u}$	1, -1	139.570	$2.60 \times 10^{-8}$	$\mu\nu_\mu$
$\pi^0$	$(u\bar{u} - d\bar{d})/\sqrt{2}$	0	134.977	$8.4 \times 10^{-17}$	$\gamma\gamma$
$K^\pm$	u $\bar{s}$ , s $\bar{u}$	1, -1	493.68	$1.24 \times 10^{-8}$	$\mu\nu_\mu, \pi\pi, \pi\pi\pi$
$K^0, \bar{K}^0$	d $\bar{s}$ , s $\bar{d}$	0	497.65	$\left\{ \begin{array}{l} K_S^0: 8.95 \times 10^{-11} \\ K_L^0: 5.11 \times 10^{-8} \end{array} \right.$	$\pi\pi$ $p\bar{\nu}_e, \mu\nu_\mu, \pi\pi\pi$
$\eta$	$(u\bar{u} + d\bar{d} - 2s\bar{s})/\sqrt{6}$	0	547.51	$5.1 \times 10^{-19}$	$\gamma\gamma, \pi\pi\pi$
$\eta'$	$(u\bar{u} + d\bar{d} + s\bar{s})/\sqrt{3}$	0	957.78	$3.2 \times 10^{-21}$	$\eta\pi\pi, \rho\gamma$
$D^\pm$	c $\bar{d}$ , d $\bar{c}$	1, -1	1869.3	$1.04 \times 10^{-12}$	$K\pi\pi, K\mu\nu_\mu, K\bar{\nu}_e$
$D^0, \bar{D}^0$	c $\bar{u}$ , u $\bar{c}$	0	1864.5	$4.1 \times 10^{-13}$	$K\pi\pi, K\bar{\nu}_e, K\mu\nu_\mu$
$D_s^\pm$	c $\bar{s}$ , s $\bar{c}$	1, -1	1968.2	$5.0 \times 10^{-13}$	$\eta\rho, \phi\pi\pi, \phi\rho$
$B^\pm$	u $\bar{b}$ , b $\bar{u}$	1, -1	5279.0	$1.6 \times 10^{-12}$	$D^*\ell\nu_\ell, D\ell\nu_\ell, D^*\pi\pi\pi$
$B^0, \bar{B}^0$	d $\bar{b}$ , b $\bar{d}$	0	5279.4	$1.5 \times 10^{-12}$	$D^*\ell\nu_\ell, D\ell\nu_\ell, D^*\pi\pi$

## Vector Mesons (spin 1)

Meson	Quark Content	Charge	Mass	Lifetime	Principal Decays
$\rho$	ud, $(u\bar{u} - d\bar{d})/\sqrt{2}$ , d $\bar{u}$	1, 0, -1	775.5	$4 \times 10^{-24}$	$\pi\pi$
$K^*$	u $\bar{s}$ , d $\bar{s}$ , s $\bar{d}$ , s $\bar{u}$	1, 0, -1	894	$1 \times 10^{-23}$	$K\pi$
$\omega$	$(u\bar{u} + d\bar{d})/\sqrt{2}$	0	782.6	$8 \times 10^{-23}$	$\pi\pi\pi, \pi\gamma$
$\psi$	c $\bar{c}$	0	3097	$7 \times 10^{-21}$	$e^+e^-, \mu^+\mu^-, 5\pi, 7\pi$
$D^*$	c $\bar{d}$ , c $\bar{u}$ , u $\bar{c}$ , d $\bar{c}$	1, 0, -1	2008	$3 \times 10^{-21}$	$D\pi, D\gamma$
$\Upsilon$	b $\bar{b}$	0	9460	$1 \times 10^{-20}$	$e^+e^-, \mu^+\mu^-, \tau^+\tau^-$

"Αλληλεπιδράσεις" μεταξύ στοιχειωδών σωματιδίων και φορέων αλληλεπιδράσεων (υπό το καλύτερο δυνατό)

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File:Elementary particle interactions.svg

From Wikipedia, the free encyclopedia

Leptons

$e, \mu, \tau$   
 $\nu_e, \nu_\mu, \nu_\tau$

Quarks

$u, c, t$   
 $d, s, b$

$S = \frac{1}{2}$   
 $S = 1$   
 $S = 0$

