PERIODIC TABLE

Atomic Properties of the Elements

NIST National Institute of Standards and Technology
U.S. Department of Commerce
Physical Measurement Laboratory www.nist.gov/pml
Standard Reference Data www.nist.gov/srd

FREQUENTLY USED FUNDAMENTAL PHYSICAL CONSTANTS§

1 second = 9 192 631 770 periods of radiation corresponding to the transition between the two hyperfine levels of the ground state of ^{133}Cs

speed of light in vacuum	c	299 792 458 m s^{-1}	(exact)
Planck constant	h	6.626 070 x 10^{-34} J s	($\hbar = h/2\pi$)
elementary charge	e	1.602 177 x 10^{-19} C	
electron mass	m_e	9.109 384 x 10^{-31} kg	
	m_ec^2	0.510 999 MeV	
proton mass	m_p	1.672 622 x 10^{-27} kg	
fine-structure constant	α	1/137.035 999	
Rydberg constant	R_∞	10 973 731.569 m^{-1}	
	$R_\infty c$	3.289 841 960 x 10^{15} Hz	
	$R_\infty hc$	13.605 693 eV	
electron volt	eV	1.602 176 6 x 10^{-19} J	
Boltzmann constant	k	1.380 65 x 10^{-23} J K^{-1}	
molar gas constant	R	8.314 5 J mol^{-1} K^{-1}	

§ For the most accurate values of these and other constants, visit pml.nist.gov/constants

Solids
Liquids
Gases
Artificially Prepared

Key (example cell):
Atomic Number: 58
Ground-state Level: $^1G^\circ_4$
Symbol: Ce
Name: Cerium
Standard Atomic Weight† (Da): 140.116
Ground-state Configuration: [Xe]4f5d6s^2
Ionization Energy (eV): 5.5386

Period 1

Group	Atomic Number	Ground-state Level	Symbol	Name	Standard Atomic Weight	Ground-state Configuration	Ionization Energy (eV)
1 IA	1	$^2S_{1/2}$	H	Hydrogen	1.008*	1s	13.5984
18 VIIIA	2	$^1S_0$	He	Helium	4.002602	1s^2	24.5874

Period 2

Group	Atomic Number	Ground-state Level	Symbol	Name	Standard Atomic Weight	Ground-state Configuration	Ionization Energy (eV)
1 IA	3	$^2S_{1/2}$	Li	Lithium	6.94*	1s^{2}2s	5.3917
2 IIA	4	$^1S_0$	Be	Beryllium	9.0121831	1s^{2}2s^2	9.3227
13 IIIA	5	$^2P^\circ_{1/2}$	B	Boron	10.81*	1s^{2}2s^{2}2p	8.2980
14 IVA	6	$^3P_0$	C	Carbon	12.011*	1s^{2}2s^{2}2p^2	11.2603
15 VA	7	$^4S^\circ_{3/2}$	N	Nitrogen	14.007*	1s^{2}2s^{2}2p^3	14.5341
16 VIA	8	$^3P_2$	O	Oxygen	15.999*	1s^{2}2s^{2}2p^4	13.6181
17 VIIA	9	$^2P^\circ_{3/2}$	F	Fluorine	18.99840316*	1s^{2}2s^{2}2p^5	17.4228
18 VIIIA	10	$^1S_0$	Ne	Neon	20.1797	1s^{2}2s^{2}2p^6	21.5645

Period 3

Group	Atomic Number	Ground-state Level	Symbol	Name	Standard Atomic Weight	Ground-state Configuration	Ionization Energy (eV)
1 IA	11	$^2S_{1/2}$	Na	Sodium	22.98976928	[Ne]3s	5.1391
2 IIA	12	$^1S_0$	Mg	Magnesium	24.305*	[Ne]3s^2	7.6462
13 IIIA	13	$^2P^\circ_{1/2}$	Al	Aluminum	26.9815385	[Ne]3s^{2}3p	5.9858
14 IVA	14	$^3P_0$	Si	Silicon	28.085*	[Ne]3s^{2}3p^2	8.1517
15 VA	15	$^4S^\circ_{3/2}$	P	Phosphorus	30.97376199*	[Ne]3s^{2}3p^3	10.4867
16 VIA	16	$^3P_2$	S	Sulfur	32.06*	[Ne]3s^{2}3p^4	10.3600
17 VIIA	17	$^2P^\circ_{3/2}$	Cl	Chlorine	35.45*	[Ne]3s^{2}3p^5	12.9676
18 VIIIA	18	$^1S_0$	Ar	Argon	39.948	[Ne]3s^{2}3p^6	15.7596

Period 4

Group	Atomic Number	Ground-state Level	Symbol	Name	Standard Atomic Weight	Ground-state Configuration	Ionization Energy (eV)
1 IA	19	$^2S_{1/2}$	K	Potassium	39.0983	[Ar]4s	4.3407
2 IIA	20	$^1S_0$	Ca	Calcium	40.078	[Ar]4s^2	6.1132
3 IIIB	21	$^2D_{3/2}$	Sc	Scandium	44.955908	[Ar]3d4s^2	6.5615
4 IVB	22	$^3F_2$	Ti	Titanium	47.867	[Ar]3d^{2}4s^2	6.8281
5 VB	23	$^4F_{3/2}$	V	Vanadium	50.9415	[Ar]3d^{3}4s^2	6.7462
6 VIB	24	$^7S_3$	Cr	Chromium	51.9961	[Ar]3d^{5}4s	6.7665
7 VIIB	25	$^6S_{5/2}$	Mn	Manganese	54.938044	[Ar]3d^{5}4s^2	7.4340
8 VIII	26	$^5D_4$	Fe	Iron	55.845	[Ar]3d^{6}4s^2	7.9025
9 VIII	27	$^4F_{9/2}$	Co	Cobalt	58.933194	[Ar]3d^{7}4s^2	7.8810
10 VIII	28	$^3F_4$	Ni	Nickel	58.6934	[Ar]3d^{8}4s^2	7.6399
11 IB	29	$^2S_{1/2}$	Cu	Copper	63.546	[Ar]3d^{10}4s	7.7264
12 IIB	30	$^1S_0$	Zn	Zinc	65.38	[Ar]3d^{10}4s^2	9.3942
13 IIIA	31	$^2P^\circ_{1/2}$	Ga	Gallium	69.723	[Ar]3d^{10}4s^{2}4p	5.9993
14 IVA	32	$^3P_0$	Ge	Germanium	72.630	[Ar]3d^{10}4s^{2}4p^2	7.8994
15 VA	33	$^4S^\circ_{3/2}$	As	Arsenic	74.921595	[Ar]3d^{10}4s^{2}4p^3	9.7886
16 VIA	34	$^3P_2$	Se	Selenium	78.971	[Ar]3d^{10}4s^{2}4p^4	9.7524
17 VIIA	35	$^2P^\circ_{3/2}$	Br	Bromine	79.904*	[Ar]3d^{10}4s^{2}4p^5	11.8138
18 VIIIA	36	$^1S_0$	Kr	Krypton	83.798	[Ar]3d^{10}4s^{2}4p^6	13.9996

Period 5

Group	Atomic Number	Ground-state Level	Symbol	Name	Standard Atomic Weight	Ground-state Configuration	Ionization Energy (eV)
1 IA	37	$^2S_{1/2}$	Rb	Rubidium	85.4678	[Kr]5s	4.1771
2 IIA	38	$^1S_0$	Sr	Strontium	87.62	[Kr]5s^2	5.6949
3 IIIB	39	$^2D_{3/2}$	Y	Yttrium	88.90584	[Kr]4d5s^2	6.2173
4 IVB	40	$^3F_2$	Zr	Zirconium	91.224	[Kr]4d^{2}5s^2	6.6339
5 VB	41	$^6D_{1/2}$	Nb	Niobium	92.90637	[Kr]4d^{4}5s	6.7589
6 VIB	42	$^7S_3$	Mo	Molybdenum	95.95	[Kr]4d^{5}5s	7.0924
7 VIIB	43	$^6S_{5/2}$	Tc	Technetium	(98)	[Kr]4d^{5}5s^2	7.1194
8 VIII	44	$^5F_5$	Ru	Ruthenium	101.07	[Kr]4d^{7}5s	7.3605
9 VIII	45	$^4F_{9/2}$	Rh	Rhodium	102.90550	[Kr]4d^{8}5s	7.4589
10 VIII	46	$^1S_0$	Pd	Palladium	106.42	[Kr]4d^{10}	8.3369
11 IB	47	$^2S_{1/2}$	Ag	Silver	107.8682	[Kr]4d^{10}5s	7.5762
12 IIB	48	$^1S_0$	Cd	Cadmium	112.414	[Kr]4d^{10}5s^2	8.9938
13 IIIA	49	$^2P^\circ_{1/2}$	In	Indium	114.818	[Kr]4d^{10}5s^{2}5p	5.7864
14 IVA	50	$^3P_0$	Sn	Tin	118.710	[Kr]4d^{10}5s^{2}5p^2	7.3439
15 VA	51	$^4S^\circ_{3/2}$	Sb	Antimony	121.760	[Kr]4d^{10}5s^{2}5p^3	8.6084
16 VIA	52	$^3P_2$	Te	Tellurium	127.60	[Kr]4d^{10}5s^{2}5p^4	9.0097
17 VIIA	53	$^2P^\circ_{3/2}$	I	Iodine	126.90447	[Kr]4d^{10}5s^{2}5p^5	10.4513
18 VIIIA	54	$^1S_0$	Xe	Xenon	131.293	[Kr]4d^{10}5s^{2}5p^6	12.1298

Period 6

Group	Atomic Number	Ground-state Level	Symbol	Name	Standard Atomic Weight	Ground-state Configuration	Ionization Energy (eV)
1 IA	55	$^2S_{1/2}$	Cs	Cesium	132.9054520*	[Xe]6s	3.8939
2 IIA	56	$^1S_0$	Ba	Barium	137.327	[Xe]6s^2	5.2117
4 IVB	72	$^3F_2$	Hf	Hafnium	178.49	[Xe]4f^{14}5d^{2}6s^2	6.8251
5 VB	73	$^4F_{3/2}$	Ta	Tantalum	180.94788	[Xe]4f^{14}5d^{3}6s^2	7.5496
6 VIB	74	$^5D_0$	W	Tungsten	183.84	[Xe]4f^{14}5d^{4}6s^2	7.8640
7 VIIB	75	$^6S_{5/2}$	Re	Rhenium	186.207	[Xe]4f^{14}5d^{5}6s^2	7.8335
8 VIII	76	$^5D_4$	Os	Osmium	190.23	[Xe]4f^{14}5d^{6}6s^2	8.4382
9 VIII	77	$^4F_{9/2}$	Ir	Iridium	192.217	[Xe]4f^{14}5d^{7}6s^2	8.9670
10 VIII	78	$^3D_3$	Pt	Platinum	195.084	[Xe]4f^{14}5d^{9}6s	8.9588
11 IB	79	$^2S_{1/2}$	Au	Gold	196.966569	[Xe]4f^{14}5d^{10}6s	9.2256
12 IIB	80	$^1S_0$	Hg	Mercury	200.592	[Xe]4f^{14}5d^{10}6s^2	10.4375
13 IIIA	81	$^2P^\circ_{1/2}$	Tl	Thallium	204.38*	[Hg]6p	6.1083
14 IVA	82	$^3P_0$	Pb	Lead	207.2	[Hg]6p^2	7.4167
15 VA	83	$^4S^\circ_{3/2}$	Bi	Bismuth	208.98040	[Hg]6p^3	7.2855
16 VIA	84	$^3P_2$	Po	Polonium	(209)	[Hg]6p^4	8.414
17 VIIA	85	$^2P^\circ_{3/2}$	At	Astatine	(210)	[Hg]6p^5	9.3175
18 VIIIA	86	$^1S_0$	Rn	Radon	(222)	[Hg]6p^6	10.7485

Period 7

Group	Atomic Number	Ground-state Level	Symbol	Name	Standard Atomic Weight	Ground-state Configuration	Ionization Energy (eV)
1 IA	87	$^2S_{1/2}$	Fr	Francium	(223)	[Rn]7s	4.0727
2 IIA	88	$^1S_0$	Ra	Radium	(226)	[Rn]7s^2	5.2784
4 IVB	104	$^3F_2$	Rf	Rutherfordium	(267)	[Rn]5f^{14}6d^{2}7s^2	6.01
5 VB	105	$^4F_{3/2}$	Db	Dubnium	(268)	[Rn]5f^{14}6d^{3}7s^2	6.8
6 VIB	106	$_0$	Sg	Seaborgium	(271)	[Rn]5f^{14}6d^{4}7s^2	7.8
7 VIIB	107	$_{5/2}$	Bh	Bohrium	(270)	[Rn]5f^{14}6d^{5}7s^2	7.7
8 VIII	108	$_4$	Hs	Hassium	(269)	[Rn]5f^{14}6d^{6}7s^2	7.6
9 VIII	109		Mt	Meitnerium	(278)		
10 VIII	110		Ds	Darmstadtium	(281)		
11 IB	111		Rg	Roentgenium	(282)		
12 IIB	112		Cn	Copernicium	(285)		
13 IIIA	113		Nh	Nihonium	(286)		
14 IVA	114		Fl	Flerovium	(289)		
15 VA	115		Mc	Moscovium	(289)		
16 VIA	116		Lv	Livermorium	(293)		
17 VIIA	117		Ts	Tennessine	(294)		
18 VIIIA	118		Og	Oganesson	(294)		

Lanthanides

Atomic Number	Ground-state Level	Symbol	Name	Standard Atomic Weight	Ground-state Configuration	Ionization Energy (eV)
57	$^2D_{3/2}$	La	Lanthanum	138.90547	[Xe]5d6s^2	5.5769
58	$^1G^\circ_4$	Ce	Cerium	140.116	[Xe]4f5d6s^2	5.5386
59	$^4I^\circ_{9/2}$	Pr	Praseodymium	140.90766	[Xe]4f^{3}6s^2	5.473
60	$^5I_4$	Nd	Neodymium	144.242	[Xe]4f^{4}6s^2	5.5250
61	$^6H^\circ_{5/2}$	Pm	Promethium	(145)	[Xe]4f^{5}6s^2	5.582
62	$^7F_0$	Sm	Samarium	150.36	[Xe]4f^{6}6s^2	5.6437
63	$^8S^\circ_{7/2}$	Eu	Europium	151.964	[Xe]4f^{7}6s^2	5.6704
64	$^9D^\circ_2$	Gd	Gadolinium	157.25	[Xe]4f^{7}5d6s^2	6.1498
65	$^6H^\circ_{15/2}$	Tb	Terbium	158.92535	[Xe]4f^{9}6s^2	5.8638
66	$^5I_8$	Dy	Dysprosium	162.500	[Xe]4f^{10}6s^2	5.9391
67	$^4I^\circ_{15/2}$	Ho	Holmium	164.93033	[Xe]4f^{11}6s^2	6.0215
68	$^3H_6$	Er	Erbium	167.259	[Xe]4f^{12}6s^2	6.1077
69	$^2F^\circ_{7/2}$	Tm	Thulium	168.93422	[Xe]4f^{13}6s^2	6.1843
70	$^1S_0$	Yb	Ytterbium	173.045	[Xe]4f^{14}6s^2	6.2542
71	$^2D_{3/2}$	Lu	Lutetium	174.9668	[Xe]4f^{14}5d6s^2	5.4259

Actinides

Atomic Number	Ground-state Level	Symbol	Name	Standard Atomic Weight	Ground-state Configuration	Ionization Energy (eV)
89	$^2D_{3/2}$	Ac	Actinium	(227)	[Rn]6d7s^2	5.3802
90	$^3F_2$	Th	Thorium	232.0377	[Rn]6d^{2}7s^2	6.3067
91	$^4K_{11/2}$	Pa	Protactinium	231.03588	[Rn]5f^{2}6d7s^2	5.89
92	$^5L^\circ_6$	U	Uranium	238.02891	[Rn]5f^{3}6d7s^2	6.1941
93	$^6L_{11/2}$	Np	Neptunium	(237)	[Rn]5f^{4}6d7s^2	6.2655
94	$^7F_0$	Pu	Plutonium	(244)	[Rn]5f^{6}7s^2	6.0258
95	$^8S^\circ_{7/2}$	Am	Americium	(243)	[Rn]5f^{7}7s^2	5.9738
96	$^9D^\circ_2$	Cm	Curium	(247)	[Rn]5f^{7}6d7s^2	5.9914
97	$^6H^\circ_{15/2}$	Bk	Berkelium	(247)	[Rn]5f^{9}7s^2	6.1978
98	$^5I_8$	Cf	Californium	(251)	[Rn]5f^{10}7s^2	6.2817
99	$^4I^\circ_{15/2}$	Es	Einsteinium	(252)	[Rn]5f^{11}7s^2	6.3676
100	$^3H_6$	Fm	Fermium	(257)	[Rn]5f^{12}7s^2	6.50
101	$^2F^\circ_{7/2}$	Md	Mendelevium	(258)	[Rn]5f^{13}7s^2	6.58
102	$^1S_0$	No	Nobelium	(259)	[Rn]5f^{14}7s^2	6.65
103	$^2P^\circ_{1/2}$	Lr	Lawrencium	(266)	[Rn]5f^{14}7s^{2}7p	4.96

†Based upon ^{12}C. () indicates the mass number of the longest-lived isotope.

*For the most accurate value, visit ciaaw.org.

For a description of the data, visit pml.nist.gov/data

NIST SP 966 (January 2017)

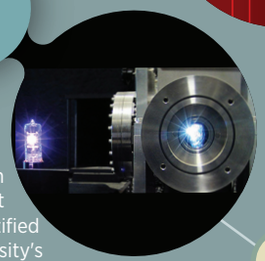
NISTory of the Periodic Table

1931

Deuterium:

This rare heavy isotope of hydrogen was concentrated at NIST and then identified by Columbia University's Harold Urey (Nobel Prize 1934). On the left is a deuterium lamp; the light on the right comes from the NIST SURF III Synchrotron Ultraviolet Radiation Facility.

Image Credit: Uwe Arp/NIST

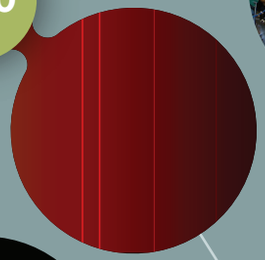


1960

Krypton:

Wavelengths of light from this atom, measured by NIST researchers, defined the official meter until 1983.

Image Credit: Neil Tucker/Wikimedia

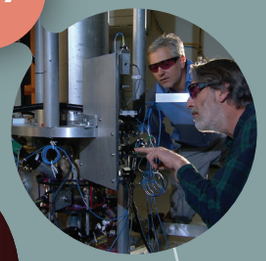


1967

Cesium:

The frequency of microwave radiation from this atom is used to define the second, measured in atomic clocks such as the NIST-F2 (2014).

Image Credit: NIST



1988

Sodium:

NIST scientists used lasers to cool a gas of these atoms to lower-than-predicted temperatures near absolute zero. (Nobel Prize 1997)

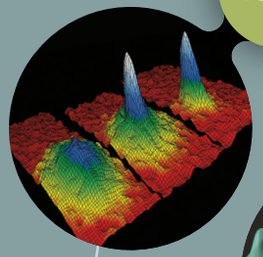
Image Credit: H.Mark Helfer/NIST

1995

Rubidium:

The atoms that created the first Bose-Einstein condensate, made by researchers at JILA (NIST-University of Colorado). (Nobel Prize 2001)

Image Credit: NIST/JILA/CU-Boulder

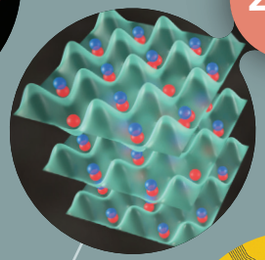


2008

Potassium and Rubidium:

JILA researchers married these elements into an ultracold gas of molecules and demonstrated striking predictions of quantum physics by hitting the atoms with "rulers of light" known as frequency combs (Nobel Prize 2005) and trapping them in webs of light known as optical lattices.

Image Credit: Steven Burrows and Ye/Jin groups/JILA

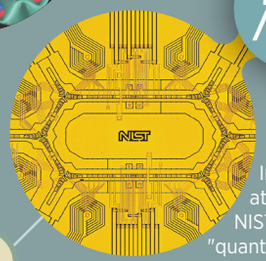


2010/2011

Beryllium and Aluminum:

Individual ions of these atoms were probed in a NIST trap to create "quantum logic" clocks that measured the second more precisely than before and tested Einstein's general theory of relativity. Such quantum manipulations were recognized in the 2012 Nobel Prize.

Image Credit: J. Amini/NIST



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