PERIODIC TABLE

Atomic Properties of the Elements

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	
	$m_e c^2$	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

Group 1 IA | 2 IIA | 3 IIIB | 4 IVB | 5 VB | 6 VIB | 7 VIIB | 8 | 9 VIII | 10 | 11 IB | 12 IIB | 13 IIIA | 14 IVA | 15 VA | 16 VIA | 17 VIIA | 18 VIIIA

Period 1

1	2
1 $^2S_{1/2}$ **H** Hydrogen 1.008* 1s 13.5984	2 $^1S_0$ **He** Helium 4.002602 $1s^2$ 24.5874

Period 2

3	4	5	6	7	8	9	10
3 $^2S_{1/2}$ **Li** Lithium 6.94* $1s^22s$ 5.3917	4 $^1S_0$ **Be** Beryllium 9.0121831 $1s^22s^2$ 9.3227	5 $^2P^o_{1/2}$ **B** Boron 10.81* $1s^22s^22p$ 8.2980	6 $^3P_0$ **C** Carbon 12.011* $1s^22s^22p^2$ 11.2603	7 $^4S^o_{3/2}$ **N** Nitrogen 14.007* $1s^22s^22p^3$ 14.5341	8 $^3P_2$ **O** Oxygen 15.999* $1s^22s^22p^4$ 13.6181	9 $^2P^o_{3/2}$ **F** Fluorine 18.99840316* $1s^22s^22p^5$ 17.4228	10 $^1S_0$ **Ne** Neon 20.1797 $1s^22s^22p^6$ 21.5645

Period 3

11	12	13	14	15	16	17	18
11 $^2S_{1/2}$ **Na** Sodium 22.98976928 [Ne]3s 5.1391	12 $^1S_0$ **Mg** Magnesium 24.305* [Ne]$3s^2$ 7.6462	13 $^2P^o_{1/2}$ **Al** Aluminum 26.9815385 [Ne]$3s^23p$ 5.9858	14 $^3P_0$ **Si** Silicon 28.085* [Ne]$3s^23p^2$ 8.1517	15 $^4S^o_{3/2}$ **P** Phosphorus 30.97376199* [Ne]$3s^23p^3$ 10.4867	16 $^3P_2$ **S** Sulfur 32.06* [Ne]$3s^23p^4$ 10.3600	17 $^2P^o_{3/2}$ **Cl** Chlorine 35.45* [Ne]$3s^23p^5$ 12.9676	18 $^1S_0$ **Ar** Argon 39.948 [Ne]$3s^23p^6$ 15.7596

Period 4

19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
19 $^2S_{1/2}$ **K** Potassium 39.0983 [Ar]4s 4.3407	20 $^1S_0$ **Ca** Calcium 40.078 [Ar]$4s^2$ 6.1132	21 $^2D_{3/2}$ **Sc** Scandium 44.955908 [Ar]$3d4s^2$ 6.5615	22 $^3F_2$ **Ti** Titanium 47.867 [Ar]$3d^24s^2$ 6.8281	23 $^4F_{3/2}$ **V** Vanadium 50.9415 [Ar]$3d^34s^2$ 6.7462	24 $^7S_3$ **Cr** Chromium 51.9961 [Ar]$3d^54s$ 6.7665	25 $^6S_{5/2}$ **Mn** Manganese 54.938044 [Ar]$3d^54s^2$ 7.4340	26 $^5D_4$ **Fe** Iron 55.845 [Ar]$3d^64s^2$ 7.9025	27 $^4F_{9/2}$ **Co** Cobalt 58.933194 [Ar]$3d^74s^2$ 7.8810	28 $^3F_4$ **Ni** Nickel 58.6934 [Ar]$3d^84s^2$ 7.6399	29 $^2S_{1/2}$ **Cu** Copper 63.546 [Ar]$3d^{10}4s$ 7.7264	30 $^1S_0$ **Zn** Zinc 65.38 [Ar]$3d^{10}4s^2$ 9.3942	31 $^2P^o_{1/2}$ **Ga** Gallium 69.723 [Ar]$3d^{10}4s^24p$ 5.9993	32 $^3P_0$ **Ge** Germanium 72.630 [Ar]$3d^{10}4s^24p^2$ 7.8994	33 $^4S^o_{3/2}$ **As** Arsenic 74.921595 [Ar]$3d^{10}4s^24p^3$ 9.7886	34 $^3P_2$ **Se** Selenium 78.971 [Ar]$3d^{10}4s^24p^4$ 9.7524	35 $^2P^o_{3/2}$ **Br** Bromine 79.904* [Ar]$3d^{10}4s^24p^5$ 11.8138	36 $^1S_0$ **Kr** Krypton 83.798 [Ar]$3d^{10}4s^24p^6$ 13.9996

Period 5

37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
37 $^2S_{1/2}$ **Rb** Rubidium 85.4678 [Kr]5s 4.1771	38 $^1S_0$ **Sr** Strontium 87.62 [Kr]$5s^2$ 5.6949	39 $^2D_{3/2}$ **Y** Yttrium 88.90584 [Kr]$4d5s^2$ 6.2173	40 $^3F_2$ **Zr** Zirconium 91.224 [Kr]$4d^25s^2$ 6.6339	41 $^6D_{1/2}$ **Nb** Niobium 92.90637 [Kr]$4d^45s$ 6.7589	42 $^7S_3$ **Mo** Molybdenum 95.95 [Kr]$4d^55s$ 7.0924	43 $^6S_{5/2}$ **Tc** Technetium (98) [Kr]$4d^55s^2$ 7.1194	44 $^5F_5$ **Ru** Ruthenium 101.07 [Kr]$4d^75s$ 7.3605	45 $^4F_{9/2}$ **Rh** Rhodium 102.90550 [Kr]$4d^85s$ 7.4589	46 $^1S_0$ **Pd** Palladium 106.42 [Kr]$4d^{10}$ 8.3369	47 $^2S_{1/2}$ **Ag** Silver 107.8682 [Kr]$4d^{10}5s$ 7.5762	48 $^1S_0$ **Cd** Cadmium 112.414 [Kr]$4d^{10}5s^2$ 8.9938	49 $^2P^o_{1/2}$ **In** Indium 114.818 [Kr]$4d^{10}5s^25p$ 5.7864	50 $^3P_0$ **Sn** Tin 118.710 [Kr]$4d^{10}5s^25p^2$ 7.3439	51 $^4S^o_{3/2}$ **Sb** Antimony 121.760 [Kr]$4d^{10}5s^25p^3$ 8.6084	52 $^3P_2$ **Te** Tellurium 127.60 [Kr]$4d^{10}5s^25p^4$ 9.0097	53 $^2P^o_{3/2}$ **I** Iodine 126.90447 [Kr]$4d^{10}5s^25p^5$ 10.4513	54 $^1S_0$ **Xe** Xenon 131.293 [Kr]$4d^{10}5s^25p^6$ 12.1298

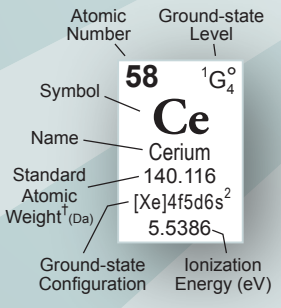
Period 6

55	56	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
55 $^2S_{1/2}$ **Cs** Cesium 132.9054520* [Xe]6s 3.8939	56 $^1S_0$ **Ba** Barium 137.327 [Xe]$6s^2$ 5.2117	72 $^3F_2$ **Hf** Hafnium 178.49 [Xe]$4f^{14}5d^26s^2$ 6.8251	73 $^4F_{3/2}$ **Ta** Tantalum 180.94788 [Xe]$4f^{14}5d^36s^2$ 7.5496	74 $^5D_0$ **W** Tungsten 183.84 [Xe]$4f^{14}5d^46s^2$ 7.8640	75 $^6S_{5/2}$ **Re** Rhenium 186.207 [Xe]$4f^{14}5d^56s^2$ 7.8335	76 $^5D_4$ **Os** Osmium 190.23 [Xe]$4f^{14}5d^66s^2$ 8.4382	77 $^4F_{9/2}$ **Ir** Iridium 192.217 [Xe]$4f^{14}5d^76s^2$ 8.9670	78 $^3D_3$ **Pt** Platinum 195.084 [Xe]$4f^{14}5d^96s$ 8.9588	79 $^2S_{1/2}$ **Au** Gold 196.966569 [Xe]$4f^{14}5d^{10}6s$ 9.2256	80 $^1S_0$ **Hg** Mercury 200.592 [Xe]$4f^{14}5d^{10}6s^2$ 10.4375	81 $^2P^o_{1/2}$ **Tl** Thallium 204.38* [Hg]6p 6.1083	82 $^3P_0$ **Pb** Lead 207.2 [Hg]$6p^2$ 7.4167	83 $^4S^o_{3/2}$ **Bi** Bismuth 208.98040 [Hg]$6p^3$ 7.2855	84 $^3P_2$ **Po** Polonium (209) [Hg]$6p^4$ 8.414	85 $^2P^o_{3/2}$ **At** Astatine (210) [Hg]$6p^5$ 9.3175	86 $^1S_0$ **Rn** Radon (222) [Hg]$6p^6$ 10.7485

Period 7

87	88	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118
87 $^2S_{1/2}$ **Fr** Francium (223) [Rn]7s 4.0727	88 $^1S_0$ **Ra** Radium (226) [Rn]$7s^2$ 5.2784	104 $^3F_2$ **Rf** Rutherfordium (267) [Rn]$5f^{14}6d^27s^2$ 6.01	105 $^4F_{3/2}$ **Db** Dubnium (268) [Rn]$5f^{14}6d^37s^2$ 6.8	106 ^{0} **Sg** Seaborgium (271) [Rn]$5f^{14}6d^47s^2$ 7.8	107 $^{5/2}$ **Bh** Bohrium (270) [Rn]$5f^{14}6d^57s^2$ 7.7	108 ^{4} **Hs** Hassium (269) [Rn]$5f^{14}6d^67s^2$ 7.6	109 **Mt** Meitnerium (278)	110 **Ds** Darmstadtium (281)	111 **Rg** Roentgenium (282)	112 **Cn** Copernicium (285)	113 **Nh** Nihonium (286)	114 **Fl** Flerovium (289)	115 **Mc** Moscovium (289)	116 **Lv** Livermorium (293)	117 **Ts** Tennessine (294)	118 **Og** Oganesson (294)

Lanthanides	57 $^2D_{3/2}$ **La** Lanthanum 138.90547 [Xe]$5d6s^2$ 5.5769	58 $^1G^o_4$ **Ce** Cerium 140.116 [Xe]$4f5d6s^2$ 5.5386	59 $^4I^o_{9/2}$ **Pr** Praseodymium 140.90766 [Xe]$4f^36s^2$ 5.473	60 $^5I_4$ **Nd** Neodymium 144.242 [Xe]$4f^46s^2$ 5.5250	61 $^6H^o_{5/2}$ **Pm** Promethium (145) [Xe]$4f^56s^2$ 5.582	62 $^7F_0$ **Sm** Samarium 150.36 [Xe]$4f^66s^2$ 5.6437	63 $^8S^o_{7/2}$ **Eu** Europium 151.964 [Xe]$4f^76s^2$ 5.6704	64 $^9D^o_2$ **Gd** Gadolinium 157.25 [Xe]$4f^75d6s^2$ 6.1498	65 $^6H^o_{15/2}$ **Tb** Terbium 158.92535 [Xe]$4f^96s^2$ 5.8638	66 $^5I_8$ **Dy** Dysprosium 162.500 [Xe]$4f^{10}6s^2$ 5.9391	67 $^4I^o_{15/2}$ **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 $^2F^o_{7/2}$ **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	89 $^2D_{3/2}$ **Ac** Actinium (227) [Rn]$6d7s^2$ 5.3802	90 $^3F_2$ **Th** Thorium 232.0377 [Rn]$6d^27s^2$ 6.3067	91 $^4K_{11/2}$ **Pa** Protactinium 231.03588 [Rn]$5f^26d7s^2$ 5.89	92 $^5L^o_6$ **U** Uranium 238.02891 [Rn]$5f^36d7s^2$ 6.1941	93 $^6L_{11/2}$ **Np** Neptunium (237) [Rn]$5f^46d7s^2$ 6.2655	94 $^7F_0$ **Pu** Plutonium (244) [Rn]$5f^67s^2$ 6.0258	95 $^8S^o_{7/2}$ **Am** Americium (243) [Rn]$5f^77s^2$ 5.9738	96 $^9D^o_2$ **Cm** Curium (247) [Rn]$5f^76d7s^2$ 5.9914	97 $^6H^o_{15/2}$ **Bk** Berkelium (247) [Rn]$5f^97s^2$ 6.1978	98 $^5I_8$ **Cf** Californium (251) [Rn]$5f^{10}7s^2$ 6.2817	99 $^4I^o_{15/2}$ **Es** Einsteinium (252) [Rn]$5f^{11}7s^2$ 6.3676	100 $^3H_6$ **Fm** Fermium (257) [Rn]$5f^{12}7s^2$ 6.50	101 $^2F^o_{7/2}$ **Md** Mendelevium (258) [Rn]$5f^{13}7s^2$ 6.58	102 $^1S_0$ **No** Nobelium (259) [Rn]$5f^{14}7s^2$ 6.65	103 $^2P^o_{1/2}$ **Lr** Lawrencium (266) [Rn]$5f^{14}7s^27p$ 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)

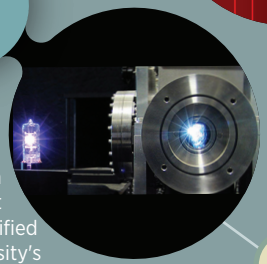
NISTory of the Periodic Table

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

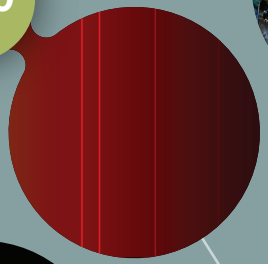


1960

Krypton:

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

Image Credit: Neil Tucker/Wikimedia

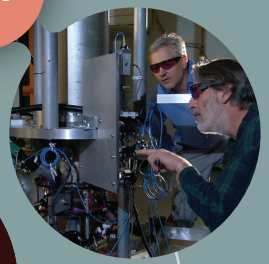


1967

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

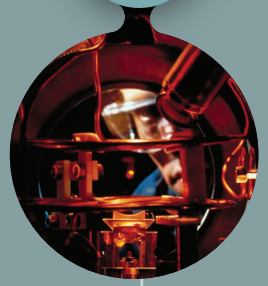


1988

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

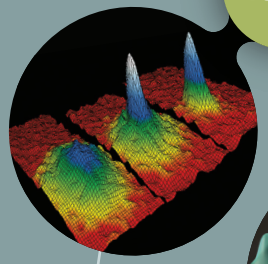


1995

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

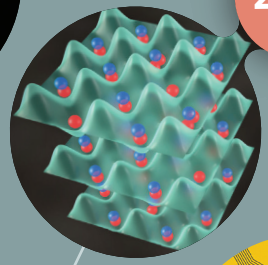


2008

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

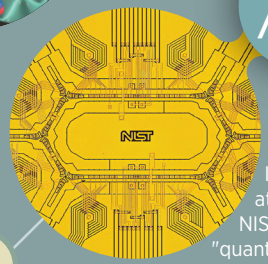


2010/2011

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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Design by: Natasha Hanacek/NIST