

PERIODIC TABLE

Atomic Properties of the Elements

NIST National Institute of Standards and Technology
U. S. Department of Commerce
Physical Measurement Laboratory www.pml.nist.gov
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	$6.626\,070 \times 10^{-34} \text{ J s}$	($h = h/2\pi$)
elementary charge	e	$1.602\,177 \times 10^{-19} \text{ C}$	
electron mass	m_e	$9.109\,384 \times 10^{-31} \text{ kg}$	
	$m_e c^2$	$0.510\,999 \text{ MeV}$	
proton mass	m_p	$1.672\,622 \times 10^{-27} \text{ kg}$	
fine-structure constant	α	$1/137.035\,999$	
Rydberg constant	R_∞	$10\,973\,731.569 \text{ m}^{-1}$	
	$R_\infty c$	$3.289\,841\,960 \times 10^{15} \text{ Hz}$	
	$R_\infty hc$	$13.605\,693 \text{ eV}$	
electron volt	eV	$1.602\,177 \times 10^{-19} \text{ J}$	
Boltzmann constant	k	$1.380\,65 \times 10^{-23} \text{ J K}^{-1}$	
molar gas constant	R	$8.314\,5 \text{ J mol}^{-1} \text{ K}^{-1}$	

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

Solids
Liquids
Gases
Artificially Prepared

Atomic Properties of the Elements

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 ¹³³Cs

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	
	R _∞	10 973 731.569 m ⁻¹	
	R _∞ c	3.289 841 960 x 10 ¹⁵ Hz	
	R _∞ hc	13.605 693 eV	
electron volt	eV	1.602 177 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	

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█ Solids
█ Liquids
█ Gases
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Group	1	2		3	4	5	6	7	8	9	10	11	12		13	14	15	16	17	18
	IA	IIA		IIIB	IVB	VB	VIB	VII	VIII	VIII	VIII	IB	IIB		IIIA	IVA	VA	VIA	VIIA	VIIIA
1	H Hydrogen 1.008* 1s 13.5984																			He Helium 4.002602 1s ² 24.5874
2	Li Lithium 6.94* 1s ² 2s 5.3917	Be Beryllium 9.0121831 1s ² 2s ² 9.3227																		Ne Neon 20.1797 1s ² 2s ² 2p ⁶ 21.5645
3	Na Sodium 22.98976928 [Ne]3s 5.1391	Mg Magnesium 24.305* [Ne]3s ² 7.6462																		Ar Argon 39.948 [Ne]3s ² 3p ⁶ 15.7596
4	K Potassium 39.0983 [Ar]4s 4.3407	Ca Calcium 40.078 [Ar]4s ² 6.1132	Sc Scandium 44.955908 [Ar]3d ¹ 4s ² 6.5615	Ti Titanium 47.867 [Ar]3d ² 4s ² 6.8281	V Vanadium 50.9415 [Ar]3d ³ 4s ² 6.7462	Cr Chromium 51.9961 [Ar]3d ⁵ 4s 6.7665	Mn Manganese 54.938044 [Ar]3d ⁵ 4s ² 7.4340	Fe Iron 55.845 [Ar]3d ⁶ 4s ² 7.9025	Co Cobalt 58.933194 [Ar]3d ⁷ 4s ² 7.8810	Ni Nickel 58.6934 [Ar]3d ⁸ 4s ² 7.6399	Cu Copper 63.546 [Ar]3d ¹⁰ 4s 7.7264	Zn Zinc 65.38 [Ar]3d ¹⁰ 4s ² 9.3942		Ga Gallium 69.723 [Ar]3d ¹⁰ 4s ² 4p 5.9993	Ge Germanium 72.630 [Ar]3d ¹⁰ 4s ² 4p ² 7.8994	As Arsenic 74.921595 [Ar]3d ¹⁰ 4s ² 4p ³ 9.7886	Se Selenium 78.971 [Ar]3d ¹⁰ 4s ² 4p ⁴ 9.7524	Br Bromine 79.904* [Ar]3d ¹⁰ 4s ² 4p ⁵ 11.8138	Kr Krypton 83.798 [Ar]3d ¹⁰ 4s ² 4p ⁶ 13.9996	
5	Rb Rubidium 85.4678 [Kr]5s 4.1771	Sr Strontium 87.62 [Kr]5s ² 5.6949	Y Yttrium 88.90584 [Kr]4d ¹ 5s ² 6.2173	Zr Zirconium 91.224 [Kr]4d ² 5s ² 6.6339	Nb Niobium 92.90637 [Kr]4d ⁴ 5s 6.7589	Mo Molybdenum 95.95 [Kr]4d ⁵ 5s 7.0924	Tc Technetium (98) [Kr]4d ⁵ 5s ² 7.1194	Ru Ruthenium 101.07 [Kr]4d ⁶ 5s 7.3605	Rh Rhodium 102.90550 [Kr]4d ⁷ 5s 7.4589	Pd Palladium 106.42 [Kr]4d ¹⁰ 7.5762	Ag Silver 107.8682 [Kr]4d ¹⁰ 5s 7.5762	Cd Cadmium 112.414 [Kr]4d ¹⁰ 5s ² 8.9938	In Indium 114.818 [Kr]4d ¹⁰ 5s ² 5p 5.7864	Sn Tin 118.710 [Kr]4d ¹⁰ 5s ² 5p ² 7.3439	Sb Antimony 121.760 [Kr]4d ¹⁰ 5s ² 5p ³ 8.6084	Te Tellurium 127.60 [Kr]4d ¹⁰ 5s ² 5p ⁴ 9.0097	I Iodine 126.90447 [Kr]4d ¹⁰ 5s ² 5p ⁵ 10.4513	Xe Xenon 131.293 [Kr]4d ¹⁰ 5s ² 5p ⁶ 12.1298		
6	Cs Cesium 132.9054520* [Xe]6s 3.8939	Ba Barium 137.327 [Xe]6s ² 5.2117		Hf Hafnium 178.49 [Xe]4f ¹⁴ 5d ² 6s ² 6.8251	Ta Tantalum 180.94788 [Xe]4f ¹⁴ 5d ³ 6s ² 7.5496	W Tungsten 183.84 [Xe]4f ¹⁴ 5d ⁴ 6s ² 7.8640	Re Rhenium 186.207 [Xe]4f ¹⁴ 5d ⁵ 6s ² 7.8335	Os Osmium 190.23 [Xe]4f ¹⁴ 5d ⁶ 6s ² 8.4382	Ir Iridium 192.217 [Xe]4f ¹⁴ 5d ⁷ 6s ² 8.9670	Pt Platinum 195.084 [Xe]4f ¹⁴ 5d ⁹ 6s 8.9588	Au Gold 196.966569 [Xe]4f ¹⁴ 5d ¹⁰ 6s 9.2256	Hg Mercury 200.592 [Xe]4f ¹⁴ 5d ¹⁰ 6s ² 10.4375	Tl Thallium 204.38* [Hg]6p 6.1083	Pb Lead 207.2 [Hg]6p ² 7.4167	Bi Bismuth 208.98040 [Hg]6p ³ 7.2855	Po Polonium (209) [Hg]6p ⁴ 8.414	At Astatine (210) [Hg]6p ⁵ 9.3175	Rn Radon (222) [Hg]6p ⁶ 10.7485		
7	Fr Francium (223) [Rn]7s 4.0727	Ra Radium (226) [Rn]7s ² 5.2784		Rf Rutherfordium (261) [Rn]5f ¹⁴ 6d ² 7s ² 6.01	Db Dubnium (268) [Rn]5f ¹⁴ 6d ³ 7s ² 6.8	Sg Seaborgium (271) [Rn]5f ¹⁴ 6d ⁴ 7s ² 7.8	Bh Bohrium (270) [Rn]5f ¹⁴ 6d ⁵ 7s ² 7.7	Hs Hassium (277) [Rn]5f ¹⁴ 6d ⁶ 7s ² 7.6	Mt Meitnerium (278) [Rn]5f ¹⁴ 6d ⁷ 7s ² 7.6	Ds Darmstadtium (281) [Rn]5f ¹⁴ 6d ⁸ 7s ² 7.6	Rg Roentgenium (282) [Rn]5f ¹⁴ 6d ⁹ 7s ² 7.6		Cn Copernicium (285) [Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7.6	Nh Nihonium (286) [Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7.6	Fl Flerovium (289) [Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7.6	Mc Moscovium (289) [Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7.6	Lv Livermorium (293) [Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7.6	Ts Tennessine (294) [Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7.6	Og Oganesson (294) [Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7.6	

Period

Atomic Number
Ground-state Level
Symbol
Name
Standard Atomic Weight (Da)
Ground-state Configuration
Ionization Energy (eV)

Lanthanides
Actinides

57 La Lanthanum 138.90547 [Xe]5d ¹ 6s ² 5.5769	58 Ce Cerium 140.116 [Xe]4f ¹ 5d ¹ 6s ² 5.5386	59 Pr Praseodymium 140.90766 [Xe]4f ² 6s ² 5.473	60 Nd Neodymium 144.242 [Xe]4f ³ 6s ² 5.5250	61 Pm Promethium (145) [Xe]4f ⁴ 6s ² 5.582	62 Sm Samarium 150.36 [Xe]4f ⁵ 6s ² 5.6437	63 Eu Europium 151.964 [Xe]4f ⁶ 6s ² 5.6704	64 Gd Gadolinium 157.25 [Xe]4f ⁷ 5d ¹ 6s ² 5.6438	65 Tb Terbium 158.92535 [Xe]4f ⁸ 6s ² 5.8638	66 Dy Dysprosium 162.500 [Xe]4f ⁹ 6s ² 5.9391	67 Ho Holmium 164.93033 [Xe]4f ¹⁰ 6s ² 6.0215	68 Er Erbium 167.259 [Xe]4f ¹¹ 6s ² 6.1077	69 Tm Thulium 168.93422 [Xe]4f ¹² 6s ² 6.1843	70 Yb Ytterbium 173.045 [Xe]4f ¹³ 6s ² 6.2542	71 Lu Lutetium 174.9668 [Xe]4f ¹⁴ 5d ¹ 6s ² 5.4259
89 Ac Actinium (227) [Rn]6d ¹ 7s ² 5.3802	90 Th Thorium 232.0377 [Rn]6d ² 7s ² 6.3067	91 Pa Protactinium 231.03588 [Rn]5f ² 6d ¹ 7s ² 5.89	92 U Uranium 238.02891 [Rn]5f ³ 6d ¹ 7s ² 6.1941	93 Np Neptunium (237) [Rn]5f ⁴ 6d ¹ 7s ² 6.2655	94 Pu Plutonium (244) [Rn]5f ⁶ 7s ² 6.0258	95 Am Americium (243) [Rn]5f ⁷ 7s ² 5.9738	96 Cm Curium (247) [Rn]5f ⁸ 6d ¹ 7s ² 5.9914	97 Bk Berkelium (247) [Rn]5f ⁹ 7s ² 6.1978	98 Cf Californium (251) [Rn]5f ¹⁰ 7s ² 6.2817	99 Es Einsteinium (252) [Rn]5f ¹¹ 7s ² 6.3676	100 Fm Fermium (257) [Rn]5f ¹² 7s ² 6.50	101 Md Mendelevium (258) [Rn]5f ¹³ 7s ² 6.58	102 No Nobelium (259) [Rn]5f ¹⁴ 7s ² 6.65	103 Lr Lawrencium (260) [Rn]5f ¹⁴ 7s ² 4.96

Atomic Number
Symbol
Name
Standard Atomic Weight[†] (Da)
Ground-state Configuration
Ground-state Level
Ionization Energy (eV)

58 $1G_4$
Ce
Cerium
140.116
[Xe]4f¹5d¹6s²
5.5386

[†]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
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NISTory of the Periodic Table

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

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

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

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

Krypton:

Wavelengths of light from this atom, measured by NIST researchers, defined the official meter until 1983.
Image Credit: Neil Tucker/Wikimedia

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

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