

## NIST Atomic Spectra Database Levels Data

Some data for neutral and singly-charged ions are available in the [Handbook of Basic Atomic Spectroscopic Data](#)

## He Spectrum

$$\vec{S} = \vec{S}_1 + \vec{S}_2$$

$$\vec{L} = \vec{L}_1 + \vec{L}_2$$

$$\vec{J} = \vec{L} + \vec{S}$$

Configuration	Term	J	Level (eV)	
1s <sup>2</sup>	<sup>1</sup> S	0	0.0	$S = 0, L = 0, J = 0$

1s2s	<sup>3</sup> S	1	19.8196134	$S = 1, L = 0, J = 1$
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S=1 lower energy  
(space anti-symm)

1s2s	<sup>1</sup> S	0	20.6157736	
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1s2p	<sup>3</sup> P <sup>o</sup>	2	20.9640857	} $S = 1, L = 1, J = 0, 1, 2$
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		1	20.9640951
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		0	20.9642176
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1s2p	<sup>1</sup> P <sup>o</sup>	1	21.2180214	
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P<sup>o</sup> odd parity  
 $\Psi(-r) = -\Psi(r)$

1s3s	<sup>3</sup> S	1	22.7184651	
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# The Periodic Table (Grand States of Atoms)

## Electron States

$$n \geq l + 1$$

$$m_l = \{l, l-1, \dots, -l+1, -l\}$$

$n$	$l$	$m_l$	Label	# of States (including $\uparrow, \downarrow$ )	Total # states
1	0	0	1s	2	2 $H \rightarrow He$
2	0	0	2s	2	4 $Li \rightarrow Be$
2	1	1, 0, -1	2p	6	10 $B \rightarrow Ne$
3	0	0	3s	2	12 $Na \rightarrow Mg$
3	1	1, 0, -1	3p	6	18 $Al \rightarrow Ar$
3	2	2, 1, 0, -1, -2	3d	10	<del>30</del> $Zn$
4	0	0	4s	2	20 $Ca$
4	1	1, 0, -1	4p	6	36 $Kr$
4	2	2, 1, 0, -1, -2	4d	10	48 $Cd$
4	3	3, 2, 1, 0, -1, -2, -3	4f	14	$Sr$
5	0	0	5s	2	38 $Xe$

Smaller  $l$  fills first



If the energy of the atom depends mainly on  $n$ , then the binding energy of the atom must drop as we go from one  $n$  to the next.

The Pauli exclusion principle forces additional electrons to occupy higher orbitals

There are  $2n^2$  states in each "shell"

# PERIODIC TABLE

## Atomic Properties of the Elements



National Institute of Standards and Technology  
Technology Administration, U.S. Department of Commerce

18  
VIII A

Period											Physics Laboratory physics.nist.gov		Standard Reference Data Group www.nist.gov/srd						
	1	2	3	4	5	6	7	8	9	10	11	12	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18	
1	<b>1</b> <b>H</b> Hydrogen 1.00794 1s 13.5984																	<b>2</b> <b>He</b> Helium 4.002602 1s <sup>2</sup> 24.5874	
2	<b>3</b> <b>Li</b> Lithium 6.941 1s <sup>2</sup> 2s 5.3917	<b>4</b> <b>Be</b> Beryllium 9.012182 1s <sup>2</sup> 2s <sup>2</sup> 9.3227																	
3	<b>11</b> <b>Na</b> Sodium 22.989770 [Ne]3s 5.1391	<b>12</b> <b>Mg</b> Magnesium 24.3050 [Ne]3s <sup>2</sup> 7.6462																	
4	<b>19</b> <b>K</b> Potassium 39.0983 [Ar]4s 4.3407	<b>20</b> <b>Ca</b> Calcium 40.078 [Ar]4s <sup>2</sup> 6.1132	<b>21</b> <b>Sc</b> Scandium 44.955910 [Ar]3d4s <sup>2</sup> 6.5615	<b>22</b> <b>Ti</b> Titanium 47.867 [Ar]3d <sup>2</sup> 4s <sup>2</sup> 6.8281	<b>23</b> <b>V</b> Vanadium 50.9415 [Ar]3d <sup>3</sup> 4s <sup>2</sup> 6.7462	<b>24</b> <b>Cr</b> Chromium 51.9961 [Ar]3d <sup>5</sup> 4s 6.7665	<b>25</b> <b>Mn</b> Manganese 54.938049 [Ar]3d <sup>5</sup> 4s <sup>2</sup> 7.4340	<b>26</b> <b>Fe</b> Iron 55.845 [Ar]3d <sup>6</sup> 4s <sup>2</sup> 7.9024	<b>27</b> <b>Co</b> Cobalt 58.933200 [Ar]3d <sup>7</sup> 4s <sup>2</sup> 7.8810	<b>28</b> <b>Ni</b> Nickel 58.6934 [Ar]3d <sup>8</sup> 4s <sup>2</sup> 7.6398	<b>29</b> <b>Cu</b> Copper 63.546 [Ar]3d <sup>10</sup> 4s 7.7264	<b>30</b> <b>Zn</b> Zinc 65.409 [Ar]3d <sup>10</sup> 4s 9.3942	<b>31</b> <b>Ga</b> Gallium 69.723 [Ar]3d <sup>10</sup> 4s <sup>2</sup> 4p 5.9993	<b>32</b> <b>Ge</b> Germanium 72.64 [Ar]3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>2</sup> 7.8994	<b>33</b> <b>As</b> Arsenic 74.92160 [Ar]3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>3</sup> 9.7886	<b>34</b> <b>Se</b> Selenium 78.96 [Ar]3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>4</sup> 9.7524	<b>35</b> <b>Br</b> Bromine 79.904 [Ar]3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>5</sup> 11.8138	<b>36</b> <b>Kr</b> Krypton 83.798 [Ar]3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>6</sup> 13.9996	
5	<b>37</b> <b>Rb</b> Rubidium 85.4678 [Kr]5s 4.1771	<b>38</b> <b>Sr</b> Strontium 87.62 [Kr]5s <sup>2</sup> 5.6949	<b>39</b> <b>Y</b> Yttrium 88.90585 [Kr]4d5s 6.2173	<b>40</b> <b>Zr</b> Zirconium 91.224 [Kr]4d <sup>2</sup> 5s 6.6339	<b>41</b> <b>Nb</b> Niobium 92.90638 [Kr]4d <sup>5</sup> 5s 6.7589	<b>42</b> <b>Mo</b> Molybdenum 95.94 [Kr]4d <sup>5</sup> 5s 7.0924	<b>43</b> <b>Tc</b> Technetium (98) [Kr]4d <sup>5</sup> 5s <sup>2</sup> 7.28	<b>44</b> <b>Ru</b> Ruthenium 101.07 [Kr]4d <sup>8</sup> 5s 7.3605	<b>45</b> <b>Rh</b> Rhodium 102.90550 [Kr]4d <sup>8</sup> 5s 7.4589	<b>46</b> <b>Pd</b> Palladium 106.42 [Kr]4d <sup>10</sup> 8.3369	<b>47</b> <b>Ag</b> Silver 107.8682 [Kr]4d <sup>10</sup> 5s 7.5762	<b>48</b> <b>Cd</b> Cadmium 112.411 [Kr]4d <sup>10</sup> 5s 8.9938	<b>49</b> <b>In</b> Indium 114.818 [Kr]4d <sup>10</sup> 5s <sup>2</sup> 5p 5.7864	<b>50</b> <b>Sn</b> Tin 118.710 [Kr]4d <sup>10</sup> 5s <sup>2</sup> 5p <sup>2</sup> 7.3439	<b>51</b> <b>Sb</b> Antimony 121.760 [Kr]4d <sup>10</sup> 5s <sup>2</sup> 5p <sup>3</sup> 8.6084	<b>52</b> <b>Te</b> Tellurium 127.60 [Kr]4d <sup>10</sup> 5s <sup>2</sup> 5p <sup>4</sup> 9.0096	<b>53</b> <b>I</b> Iodine 126.90447 [Kr]4d <sup>10</sup> 5s <sup>2</sup> 5p <sup>5</sup> 10.4513	<b>54</b> <b>Xe</b> Xenon 131.293 [Kr]4d <sup>10</sup> 5s <sup>2</sup> 5p <sup>6</sup> 12.1298	
6	<b>55</b> <b>Cs</b> Cesium 132.90545 [Xe]6s 3.8939	<b>56</b> <b>Ba</b> Barium 137.327 [Xe]6s <sup>2</sup> 5.2117																	
7	<b>87</b> <b>Fr</b> Francium (223) [Rn]7s 4.0727	<b>88</b> <b>Ra</b> Radium (226) [Rn]7s 5.2784																	

**Frequently used fundamental physical constants**

For the most accurate values of these and other constants, visit [physics.nist.gov/constants](http://physics.nist.gov/constants)

1 second = 9 192 631 770 periods of radiation corresponding to the transition between the two hyperfine levels of the ground state of <sup>133</sup>Cs

speed of light in vacuum	<i>c</i>	299 792 458 m s <sup>-1</sup>	(exact)
Planck constant	<i>h</i>	6.6261 × 10 <sup>-34</sup> J s	( <i>h</i> = <i>h</i> /2π)
elementary charge	<i>e</i>	1.6022 × 10 <sup>-19</sup> C	
electron mass	<i>m<sub>e</sub></i>	9.1094 × 10 <sup>-31</sup> kg	
	<i>m<sub>e</sub>c<sup>2</sup></i>	0.5110 MeV	
proton mass	<i>m<sub>p</sub></i>	1.6726 × 10 <sup>-27</sup> kg	
fine-structure constant	<i>α</i>	1/137.036	
Rydberg constant	<i>R<sub>∞</sub></i>	10 973 732 m <sup>-1</sup>	
	<i>R<sub>∞c</sub></i>	3.289 842 × 10 <sup>15</sup> Hz	
	<i>R<sub>∞hc</sub></i>	13.6057 eV	
Boltzmann constant	<i>k</i>	1.3807 × 10 <sup>-23</sup> J K <sup>-1</sup>	

Solids  
 Liquids  
 Gases  
 Artificially Prepared

Atomic Number: 58  
 Ground-state Level: 1G<sub>4</sub>  
 Symbol: **Ce**  
 Name: Cerium  
 Atomic Weight: 140.116  
 Ground-state Configuration: [Xe]4f5d6s<sup>2</sup>  
 Ionization Energy (eV): 5.5387